

REPLACEMENT DESIGN STUDY
FOR
LIGHTER AMPHIBIOUS RE-SUPPLY CARGO 5 TON
Amphibious Vehicle LARC V



Major Report in Partial Fulfillment of Requirement for M.E.O.E

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ABSTRACT

This project examines LARC V, which is water and land interface vehicle designed for support of amphibious operations (troops and cargo transport) in rivers and protected waters. Vehicle's mission evolved to more stringent, involving amphibious assault operations in the highly demanding surf zone, as well as support of the dive and salvage operations. The age (35 years), and increasing requirements, including weight, stability, range, speeds, and reliability dictated study on improvement or replacement of the existing design. Research concentrates on conceptual study and development of various options for presentation to the sponsor, U.S. Navy Ocean Facilities Program (OFP), and the ultimate owner, U.S. Navy, Underwater Construction Teams.

"The very act of studying something may change it."

(Earl Babby)

* Cover page photo represents LARC V, UCT Dive Platform [Ref. 8]

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PROJECT PROPOSAL

Title:

U.S. Navy, Underwater Construction Team (UCT) LIGHTER, AMPHIBIOUS, RE-SUPPLY, CARGO, 5-TON (LARC-V) REPLACEMENT DESIGN STUDY

Project Description:

The study concentrates on redesign of the LARC V (Lighter, Amphibious, Replenishment, Cargo, 5-Tons), currently used by the U.S. Navy Underwater Construction Team (UCT) as a platform for diving operations. The U.S. Navy's Naval Facilities Engineering Command (FACENGCOM) initiated this project in order to replace existing aged vehicle. The strategy of this project is a preliminary trade off study of technical approach, owner's requirements study (including a field trips to the UCT 1 and 2), and two alternative improvement and conceptual designs. The following elements constitute the planned scope of the project:

1. Development of owner's requirements, based on trade off studies of amphibious crafts and similar systems, and interviews with operators (including test-drive).
2. Selection of conceptual technical approaches and alternative solutions.
3. Design of vessel principle characteristics such as weight estimate, curves of form, lines drawing, inboard profile and deck arrangements, capacity plan, machinery arrangements, structural midship section, speed and power analysis, propulsion plant trade-off and fuel endurance calculation, electrical load analysis, sea keeping analysis, area/volume summary, manning estimate, major HM&E, and cost analysis.

Goals:

The ultimate goal is to develop an attractive design of amphibious vehicle in support of diving operations or improvement of performance of existing craft on land and at sea in support of diving and amphibious operations. However, in order to better accommodate the owner based on wide and unclear set of missions, an improved existing design and alternative conceptual design are goals of this study.

Chapter 1. INTRODUCTION

The subject study was initiated by COMNAVFACENGCOM. The design of Lighter, Amphibious, Re-Supply, Cargo, 5-Ton (LARC V) amphibian craft was performed in the late 1950s by U.S. Army Transportation Research Command. Initial requirement was for use in rivers and protected waters in support of amphibious operations. Those requirements evolved to surf zone salvage, and in case of UCT, additional requirements such as support of underwater construction and various survey diving operations. Such evolution imposed intolerable additional stresses on the vehicle's components, beyond design performance parameters. Additionally, the required range of the vehicle and land and waterborne speed are increased beyond the limits of existing performance, where pre-boating of LARC V is required to get it ashore. The maintenance cost and reliability of the vehicle also suffer as systems such as traction, power transmission, and vehicle handling components wear out or fail at increased rates. The cost also increase due to age of the parts, which no longer are obtainable by direct purchase and have to be custom manufactured or refurbished by specialized units. These issues make supportability and operational values of LARC V questionable.

In order to minimize failures and improve operating parameters a modifications or new vehicle concept seem unavoidable. As a result, a preliminary research and a field trip to the Underwater Construction Team Two and One were conducted to review vehicle's components and develop a list of potential modifications to improve LARC's performance.

The comparison study was performed based on the existing redesign of the Marine Corps Assault Amphibious Vehicle (AAV) to Advanced Assault Amphibious Vehicle (AAAV), where parameters such as speed, and range were increased from identical for existing LARC V to parameters similar to expected from new LARC. The AAV redesign was chosen for its hull parameters and size are similar to LARC V. This study allowed rough estimate of expected power increase in order to achieve upgraded requirements of speed and range.

In addition, the existing LARC V and modified vehicle were modeled using the AUTOSHIP software. In case of the modified LARC V, the wheels were covered by

hydrodynamic appendages and hull was faired in the bow section. The length, beam, draft, weight, and other parameters were maintained constant for comparison analysis.

The hydrostatic parameters and hull forms were calculated in order to input those values into AUTOPOWER software for further tradeoff analysis. The above steps started the conceptual design, which was continued and expanded in the second part of this project, where resistance and effective powers for various scenarios and hulls was evaluated using AUTOPOWER program.

Finally, alternative conceptual design of demi-hull, Dive Platform Catamaran (DPCAT), was developed and analyzed, including resistance and effective power calculations.

Topic familiarization however was the first step of this study in order to help understand the owner's requirements, select technical approach, and perform trade off studies with alternative solutions (designs).

Various literary sources (see bibliography) on the subject of existing craft systems and similar systems under development were reviewed. The UCT 2 and UCT 1 were visited, including operator / maintenance and management personnel interviews, and test drive was performed on 18 December 2003. Numerous photos were taken and relevant technical manuals were reviewed. Findings are discussed in the following section.

Chapter 2. BACKGROUND

In 1956 the original LARC V was designed by the US Army Transportation Research Command with the mission to provide lighter service for cargo and troops to and from the beach. The Ingersoll Kalamazoo Division of Borg-Warner built the prototype in 1958 and the initial production followed in 1962 by LaTourneau-Westinghouse, and later by Consolidated Diesel Electric Corporation. Almost one thousand units weighting 16,000 [lbs] were manufactured to carry 10,000 [lbs] of cargo at 10 [mph] waterborne. In the process of operation it was discovered that vehicles were of great value in providing assistance to stranded vehicles, and design was modified (including replacement of gasoline engine with diesel one), thus increasing empty weight to 20,000 [lbs] and limiting weight of cargo to 6,000 [lbs] (~3 Tones). Effectively the maximum waterborne speed was further reduced. In addition, the reliability of the drive train was reduced, as it was not adjusted to 8 cylinder Cummins V-903C diesel engine rated at 295 BHP, and new surf-zone salvage operations, which included towing of disabled vehicles. The stability of the vehicle was also threatened by large swell in the surf-zone.

Vehicle's Mission

The current and anticipated missions of the LARC include: salvage operations in the surf zone; laying tag lines for towing disabled or broached crafts; removing obstacles; placing navigation aids; providing towing services; extracting broached landing craft; transporting personnel (troops, POW's, refugees and casualties); surf zone firefighting; utilization as a diving platform; assisting with LCU ramp closure; assisting with hydrographic operations; dewatering assistance; rescue services; and other unanticipated services. The craft is capable (not necessarily designed) to traverse sand and coral beaches, negotiate through a surf of 10-foot breakers, unimproved roads (off-road terrain), and operate in tropic and arctic climates. The engine is located in the stern over the hull tunnel (nozzle) propeller. It drives forward to a centrally located transfer case,

which transmits power to the all wheels and the propeller shaft. Vehicle's suspension is rigid based on 18.00X24-12 tires providing the only shock absorption and road contact control. The modification weight increase decreased cargo capacity from 10,000 pound to approximately 6,000 [lbs] payload (3 short tons).

The hull tunnel, fitted with nozzle, hoists the propeller and its size is limited by the ground clearance.

Some critical factors considered in this study and requiring improvement in order to satisfy the above listed requirements include increased speed when waterborne and on land (maintaining convoy integrity); increased reliability of the land-pulling capability (excessive stress on drive train and strain on structural integrity); increased stability (survivability in the surf zone).

The following Table 2.1 represents the general characteristics of the existing LARC V, including engine, electrics, overall dimensions, cargo space dimensions and capacity, ground clearance, and various operational parameters.

LARC – V Characteristics

Manufacturers: Le Torneau - Westinghouse Corp. (Adams Div) and later Consolidated

Diesel Electric Corp. (Ingersoll Kalamazoo Division of Borg-Warner built the prototype)

Construction: Aluminum

Table 2.1 Existing LARC V Parametric Description [ref. 3 & 7]

Engine:	Performance data:
Make..... Cummins (initially G.M.)	High range speed land.....30mph.
Type.....V8	Low range speed land.....8mph.
Model..... V-903C	Water speed..... 9.5 knots
Power..... 295 h.p.	Grade limits..... 60% @ 1 mph.
Revs full..... 2,600rpm.	
Revs idle..... 650rpm.	
Electrics:	Turning radius:
24vdc insulated earth return.	Land.....41ft. 3in.
Overall Dimensions:	Outside clearance radius min....36ft. 6in.
Length.....35ft.	Inside clearance radius min.....26ft 6in.
Width over tires.....10ft.	Water turning radius.....36ft.
Overall height.....10ft. 2in.	
Wheelbase.....16ft.	
Freeboard (amidships loaded).....10in.	
Clearances:	Fuel consumption (maximum):
Hull to ground 2ft.	Land.....6gph. imp.
Propeller shroud to ground 16 in.	Sea.....12gph. imp.
Cargo space:	Weights:
Length.....16ft.	Net. inc. crew and fuel.....19000 lbs.
Width.....9ft. 9in	Maximum payload.....10,000lbs.
Depth (side panels).....2ft. 5in	Total gross30,000lbs
	Tires:
	18in x 25in 12ply
	Hard surfaces bow 18psi.....stern 22psi.
	Soft surfaces bow 9psi.....stern 14psi.
	Shipping all round.....50psi.

Owner's Requirements (UCT2 and UCT1)

During visit to UCT2, an operators and mechanics were interviewed as well as unit's leadership. Numerous digital photos were taken and one vehicle was driven into the harbor for a test drive. The main concerns of the interviewed personnel were with vessel's stability (in the surf zone), performance (speed and range), deck space, and equipment compatibility (equipment mounting, vessel mooring, towing, and anchoring) for team's operations, and finally with vehicle's drive and power systems. Those concerns are discussed in greater depth in the following paragraphs.

It was pointed out that the craft underwent capsizing in the surf zone. As stated earlier the hull was designed for river and protected water operations, where in the surf zone a modifications to the hull and center of gravity configurations, increased power, thus ultimately maneuverability are required. The vessel's bilge plug and pump system was discussed and it was agreed that improvements are also required. Current arrangement allows water entering the hull while plugs are not secured, thus system preventing flooding when plugs are not secured was sought (i.e. buoyant floats, one-way check valves, etc.).

One of many vehicles' deficiencies is its inability to cover large distances (up to 400 miles required). In addition, though it has listed range of 200 nautical miles on land (40 nm on water), the vehicle is hauled by the tractor within five miles of the water. Vehicles current speed on land and waterborne is far from reaching expectations or even requirements of listed design performance. For example, required speeds are 70 MPH, highway (demand on suspension and steering capacity) and 40 MPH on sand versus available 22 MPH, with 30 MPH design baseline when fully loaded. Similarly in the water expected speeds are exceeding 20 knots, while available is only 6.5 knots (9 MPH listed). [ref.3]

LARC – V was not developed as a dive platform, thus it does not provide the most effective dive support. Required is dive station with Surface Supplied Dive side (including a compressor), removable twin scuba tank storage (similar to those used on YDT's at Diving Center in Panama City), let in or recessed ladder, and other diving

operations components such as 20 pair of twin SCUBA cylinders, drawers for MK-21 helmets, roll up doors for dive gear, windlass, anchors, fresh water rinse down, etc.).

The practical mooring, towing, and anchoring system with proper cleats, bollards, capstan (including a self-recovery winch), bumpers and fenders, etc. The current exhaust system gets in direct contact with the synthetic mooring lines resulting in melting the lines. The stowage for that equipment also was presented as problematic (no proper space provided for ready access). Sea handling equipment and particularly weapons, ammunition, communications equipment requires a dry storage space. Sufficient dry storage below deck with easy access scuttles that are low maintenance and airtight shall be provided. The proper mounting for the caliber 50 weapon was also discussed. It was pointed that some kind of an overhead cover (perhaps compatible with MTVR canvas) would improve work environmental conditions (sun, rain) for the topside personnel. The current deck arrangement amidships with small freeboard seems to be optimal for diving operations and Zodiac motor boat operations; although an improved boat launch and recovery system is required. The deck arrangement is also favorable for cargo handling (vehicle's initial requirement), where components such as bridge spans, or foundations might have to be transported in support of underwater construction.

Interviewers requested that the critical vessel's system be more reliable and its capacity increased. The compatibility of the engine and other components with the Marine Corps MTVR (see appendix 2) was discussed. MTVR's engine capacity is 425 [HP], which might be an answer to the requirement of increased power necessary to achieve the waterborne speed and maneuverability. The water jet implementation is sought, as used in AAV and other amphibious vehicles [ref. 11]. In this case safety would be improved and limit on propeller size due to ground clearance would be eliminated, or diminished. Additionally, considering large size of the main engine, it might be desirable for efficiency to have a small auxiliary engine to support dive or other operations while at anchor.

Increased mission requirements, beyond rated capacity, resulted in decreased reliability and diminished availability of the replacement parts. Perhaps the most critical component, the drive train, was not developed for current type of engine (diesel versus gasoline), as well as the increased requirements of demanding missions in the surf zone

salvage. This important aspect (maintenance and cost critical) of the vehicle's reliability could be addressed by implementing an all wheel drive, which would be based on hydrostatic drive (possibly other improved arrangement) versus existing right angle direct drive (prone to damage in the surf zone operations).

In addition, it was pointed out that the vehicle will have to be transported on a plane, with C-17 being a most feasible aircraft. This presents additional limits on the size of the vehicle. It was noted that the smaller size of the vehicle is not desired, thus not allowing for highway standardization of existing vehicle. The current beam is 10' versus allowable (without additional permit) is 8'6". This could be addressed in new vehicle design by dual hull design, which would allow adjustable beam.

Additional improvements like safety, crew comfort, reliability, and maintainability, are listed in the [Ref. 3]. Suggested improvements in that reference, resulted from study done in 1999 for the NAVFAC by John J. McMullen Associates (JJMA) mostly at the Beachmaster Units (BMUs) at Naval Beach Group Two (NBG2) and Construction Equipment Department (CED), CBC Gulfport, MS. [Ref. 3] also lists further requirements as viewed by the BMUs versus UCTs.

Chapter 3. METHODOLOGY

The first approach of this study, after gathering owner requirements, was to estimate power required to increase the speed to expected value above 20 knots. The existing modification and improvement program performed by the Marine Corps on its Amphibious Assault Vehicle (AAV) was studied. AAV's parameters were found to be similar to those of LARC V, thus comparison analysis were possible. AAV was upgraded to an Advanced Amphibious Assault Vehicle (AAAV), with the scope similar to that expected for LARC V. Values were compared and expected values were estimated for improved LARC.

It was noted that direct power density comparison was not sufficiently accurate and that further analysis of hull form modification, alternative propulsion system, and other hydrodynamic appendages were required to arrive at realistic estimated required power for improved LARC.

At that stage, two models of original and improved LARC were formed using AUTOSHIP and values such as hydrostatic parameters, weights, displacements, planes areas, hull form coefficients, wetted surface areas, centroids, and metacenters were calculated for input to the AUTOPOWER for resistance and power calculations. The results were compared with the results of comparison study done on AAAV. The analysis were performed and results used to establish the viability of estimated power required to achieve expected speed by modified hull versus existing LARC V.

Finally, new conceptual design of Dive Platform Catamaran (DPCAT) was developed and analyzed for resistance and effective power. The conceptual design is based on the dual hull vehicle with adjustable beam. Retractable wheels allow minimization of the resistance, thus increased performance while waterborne. Power and resistance analysis were performed for maximum beam with folded wheels. In addition, the structural beam connecting the two hulls of the catamaran was analyzed for local primary stresses at the supports.

Various hull scenarios were compared and recommendations were discussed. Results are presented and evaluated in the following section.

Chapter 4. ANALYSIS AND EVALUATION

LARC V and AAV Comparisons

In the course of this project the Marine Corps AAV was considered and comparative analyses were performed. The size of both vehicles is similar with large variability in weight. The former AAV capabilities are similar to present LARC V, where AAV capabilities are similar to required redesigned LARC, 'dive vehicle'. For example AAV's speed in the water was increased from 6~8 MPH to 23~29 MPH. Range on water was increased from 45 to 65 miles.

Appendix 5 presents in Table 2 the results of comparison calculations between modifications done to upgrade Amphibious Assault Vehicle (AAV) to Advanced Amphibious Assault Vehicle (AAAV). This upgrade increased AAV's speed from 6~8 MPH to 23~29 MPH waterborne, 30[MPH] to 45[MPH], and improved range. Most of size and operating parameters of AAV such as speed and power were found to be almost identical to LARC V [ref. 4]. The results were applied to LARC V and based on the power density analysis, and increase in required power for improved LARC was estimated. The parameters and characteristics of AAV and AAAV are presented in appendixes four and five. The comparison analysis based on direct power density calculations revealed that improved LARC would require 1037 [HP], which is a rather large and perhaps unacceptable power demand on this size of vehicle. At this point, it is assumed to be an upper bound on the required power for improved LARC.

Based on scaling of transverse (immersed) areas due to AAAV's larger beam (12' versus 10' for that of LARC V), and larger draft (approximately 7' versus 4'), it was concluded that scaled expected power required for modified LARC to achieve speed above 20 knots would be approximately 494 [HP] (see appendix 5). The resulting power required was calculated based on the following relation $1037[\text{hp}] * (\text{A}_{\text{AAAV}} / \text{A}_{\text{LARC}}) = 494[\text{hp}]$.

The similarities were analyzed based on data presented in Appendix 4 and Reference 4. Results are provided in Table 2 of Appendix 5. Direct comparisons with

the AAAV, ($[P_{\text{density}_{\text{LARC}}} / P_{\text{density}_{\text{AAAV}}}] * W_{\text{LARC}}$, see appendix 5), were performed under assumptions given in section 4, and conclusions were drawn that between 494 and 1037 [HP] would be required from new engine. Because AAAV's draft is much greater than that of LARC due to the weight (vehicles are of similar size, but varying density), and because LARC's beam is 2" smaller, the lower bound is 494 [HP]. This bound becomes more realistic under condition that modified vehicle is propelled by two water jets versus LARC's single propeller. Above comparison is not very accurate, but it does give an estimate of expected lower and upper bound in engine power requirements for the required vehicle.

Under closer scrutiny other components such as displaced volume, inertia coefficient, added mass, wave making characteristic, and drag coefficient should be considered. However, this simplified analysis point out that it is possible to achieve hull resistance compatible with 425 [hp] delivered by the MTVR engine (required by the owner).

The study done by the John J. McMullen Associates, Inc. commissioned by Naval Facilities Engineering Command and described in reference 3, indicates that, based on assumption that engine horsepower varies closely with the cube of the craft's speed (Vk^3), even large increase in power will only increase speed by small amount. Thus, achieving a half-not increase in maximum speed (6.89 knots to 7.39 knots) would require increase in power of 23% (292 BHP to 360 BHP). Accordingly, increase of full knot would require 438 BHP, or a 50%. As seen, with expectations of speed above 20 knots, this trend would require unrealistic amount of power to satisfy the owner requirement. This study, based on speed trials data, indicates that no significant improvement in craft speed is possible without hydrodynamic modifications. The propeller's low efficiency (approximately 37%) and constraint on propeller diameter further decrease effects of power increase and suggest implementation of an alternative propulsion system.

Certainly, further study is required to find out the best propulsion components for their feasibility and compatibility. It seems that two water jets, powered by more powerful engine, might be a best option considering a propeller ground clearance constraint.

LARC V and Modified LARC Modeling

In next phase of the project LARC V and modified LARC were modeled using AUTOSHIP software. The results were used for resistance and power calculations in AUTOPOWER software. Two vehicles were compared with each other and with the results of similarity study of AAAV. Further analysis were performed and results were used to establish the viability of estimated power required to achieve expected speed by modified hull versus existing LARC V.

Appendices 6 through 9 represent analysis performed using AUTOSHIP software. Two models of existing LARC V and modified LARC were formed and various hydrostatic parameters calculated. Weights, displacements, planes areas, hull form coefficients, wetted surface areas, centroids, and metacenters were calculated to use as an input to the AUTOPOWER, in which resistance and estimated power were calculated.

The existing LARC V was modeled based on parameters presented in Appendix 10, the LARC V characteristics. Hull form was modeled based on the weights, beam, length, freeboard, draft, and other dimensions given in Appendix 10 and Table 1 for LARC V. Modeling presented some challenges due to unconventional hull form of the vehicle such as bow and wheel well areas. The hull weight was represented as individual aluminum plate weight, while machinery, equipment, and inner hull weights were represented as two cubes concentrated masses located at the centerline of the model in locations resulting in desired longitudinal center of gravity. Although the hull tunnel hoisting the propeller was not modeled, a fitted nozzle was modeled as a horizontal cylinder and was included in this model (see Figure 11~12). The line drawings and renderings of this model are presented in Appendix 6.

The modified LARC was modeled based on required underbody and wheel fairings. It required reshaping the bow and the hull forward of wheels to divert flow around the wheels (see Figure 14~16). In addition, retractable plates were added along the inner and outer edges (including wheel wells) to improve flow, thus further reducing resistance. The outer hydrodynamic appendages were modeled as vertical plates (restricted by wheels), with attached bottom plates angled outboard for ease of mechanical operation and favorable hydrodynamic force distribution as well as flow

improvement (see Figure 13~16). The inner hydrodynamic appendages were modeled as vertical plates with only slight angle to vertical in order to improve hydrodynamic flow and favorable force distribution on the plate.

Effectively entire wheel wells and the wheels were encased, which is considered a simplification as in real situation this might not be feasible. The hull tunnel hoisting the propeller and fitted nozzle were not modeled in this version in anticipation of water jet propulsion system, which might be implemented in the improved model.

The hydrostatic values and contour drawings of both models are presented in appendixes 8 through 9 and 6 respectively. Hull form parameters are presented in Appendix 7 as an input to AUTOPOWER resistance and propulsion calculating program. It shall be noted that metacentric radius decreased for the modified LARC model. Coefficients of water plane and midship section, as well as wetted surface areas vary as expected, and draft and displacements vary slightly.

The calculations of resistance and power were carried in the next phase using full version of the AUTOPOWER program and results are presented in the following section of this report.

LARC Resistance and Power Calculations and Comparisons

The calculations were performed to estimate the resistance and power required for LARC V, as well as for the modified LARC version described in the preceding section. The AUTOPOWER program was used with displacement and planning hull methods utilized. In case of displacement hulls, the power and resistance difference between the two hulls follow expectations with only approximately 10% improvement after fairing the LARC V hull. The Fung and Holtrop methods were utilized as shown in the Appendix 11.

The planning hull assumption was also made and analyzed with results showing no significant difference in resistance or effective power. Various Savicki's and Radojcic methods were used as shown in appendix. Results are presented in the Appendix 7. All methods were limited by certain Froude number, thus values for some speeds were not

obtained with only one method, thus two varying methods were used for both displacement and planning hulls.

There exist an agreement between results of this study and the empirical results of test run done by the John J. McMullen Associates, Inc., in their Product Improvement Study. The approximate effective power using Fung method for lower Froude number proves a better estimator for this case. The Holtrop method is used for wider range of Froude number. However, it departs from the empirical results and underestimates required power. Nonetheless, when used in tandem, those two methods provide a range of what one could expect at wide range of Froude number.

The following phase of the project concentrated on development of alternative new design based on dual hull (demi-hull) with adjustable beam and water jet propulsion applied in that alternative.

Dive Platform Catamaran (DPCAT) Modeling

Hull form design is one of the most important challenges in shipbuilding industry. The demi-hull (catamaran) of variable beam and water jet propulsion is considered in this phase of the project. The propulsive coefficient for the catamarans varies with the type of propulsion. The most common types are water jets, propeller with inclining shaft, propeller with aft body tunnel, and Z-drive. The corresponding propulsive coefficients are 0.62~0.64, 0.64~0.65, 0.7~0.8, and 0.68~0.7 respectively. It is immediately noticed that water jet propulsion is not the most efficient. However, the safety concerns associated with each type and its relevance to dive operations, as well as relatively small average efficiency benefit, suggest implementation of the water jet type propulsion for the dive platform. Additional benefits of the water jets are improved maneuverability, and increased ground clearance, whereas factors of concern include faulty operations in rough seas, such as surf zone.

It is assumed that vehicle is towed ashore, with only limited self propulsive capability via electric or hydraulic drive while on land. It is also assumed that the vehicle's wheels are retractable or dismountable, thus disregarded in resistance calculations. The hydrofoil version was not a part of this study, but its benefits and feasibility should be considered as resistance becomes greatly decreased during normal

sailing; since designated part of the vessel is lifted above the free surface due to dynamic lift. This scenario would be applicable only for a particular loading condition, as the water jets would come out of the water if load too small was applied; or benefit of the dynamic lift would not be achieved in opposite case. The bottom line is that for small size ships, the amount of resistance reduction due to the foil system is up to 60% from the bare hull resistance [Ref. 15]. The loading is a very important aspect of the catamaran design, as it might significantly hinder its operational capability; when for example vehicle could not continue the high speed sailing due to excessive drag. Thus the selection of the design base weight (displacement) is related to initial estimation of required power [Ref. 15]. For this study a vehicle with five metric tons ($\sim 10,000$ [lbs]) and gross weight of approximately 16 [T] ($\sim 30,000$ [lbs]) is considered. This complies with MTVR's towing capacity of 11 [T], empty vehicle.

Catamaran vehicles offer many practical advantages in form of large deck area, high stability, superior maneuverability, easy operation and maintenance [Ref. 15].

The DPCAT was modeled using same AUTOSHIP program and was based on LARC V characteristics, as same length and draft was used with only beam scaled down by half. In other words the model of LARC V was split longitudinally in two. In addition no wheels and propeller tunnel was included, as retractable wheels and water jet propulsion was assumed. The two hulls are structurally joined by two beams; which also serve to adjust the beam of the demi-hull from minimum 2.6 [m] to maximum of 5.2 [m]. The figures presenting DPCAT model and its characteristics are presented in the Appendix 11.

Hull Connecting Beam Analysis

The following analysis was motivated by the undergoing study of the amphibious vehicle redesign. The vehicle was modeled as a catamaran with variable beam span (see Figure 4.1). The beam is adjustable via two hull-connecting boxed girders, which are subject of this study.

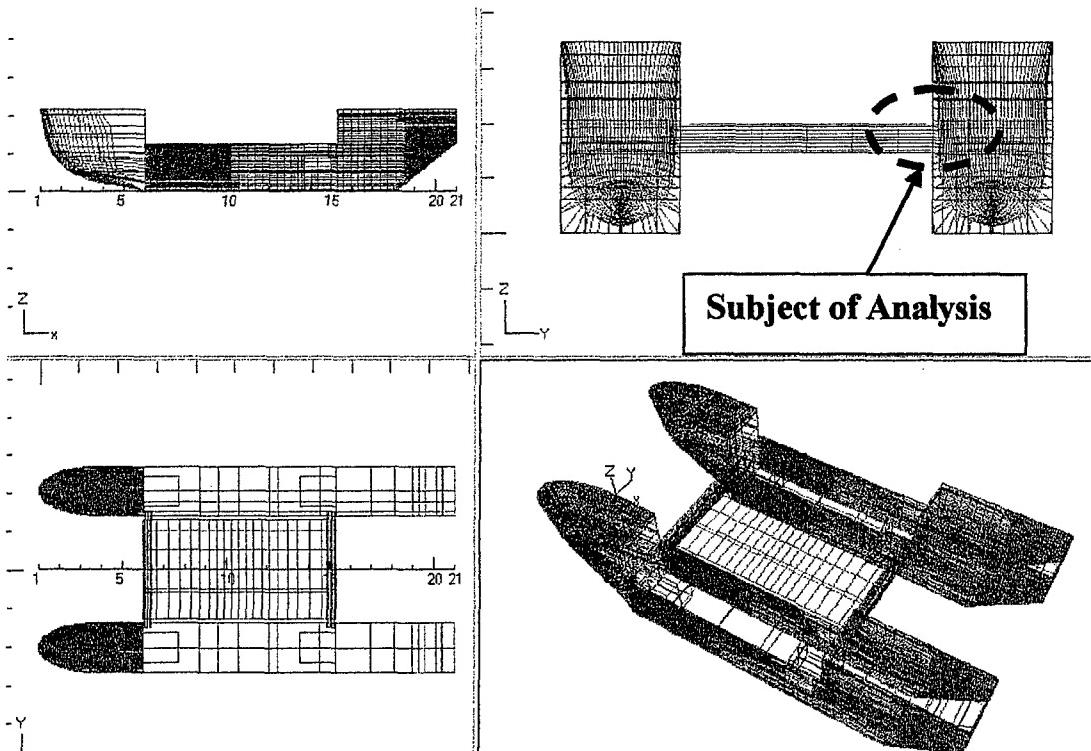


Figure 4.1 Vehicle Concept

Deterministic approach, selected for this structure generation, is followed. Such approach to structure generation involves: guess of the configuration, estimating loads acting on the structure, structure analysis for stress adequacy.

Transversely loaded and uniform cross section boxed girder of wall thickness t is considered with cross section of width b (flange) and web height a (see figure 4.2).

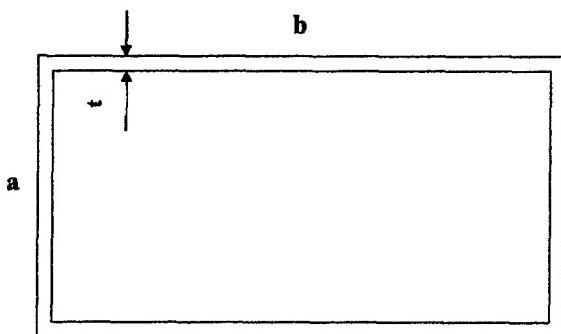


Figure 4.2 Boxed Girder Cross Section

Primary Parameters and Load Determination

The cross sectional dimensions of the girder are $a = 0.3$ [m], $b = 0.2$ [m], and the girder wall thickness is $t = 0.01$ [m].

Various load cases were analyzed in order to most accurately apply a lateral vertical load q on top and bottom faces of left end of the beam. The following figures represent the selection process.

Initially the scenario of beam fixed at one end and free to deflect vertically, but restricted to rotate, was approached since it closely resembles a beam with the hull attached to it at the opposite end. The hull action results in some moment at the 'free' end of the cantilever (see Figure 4.3).

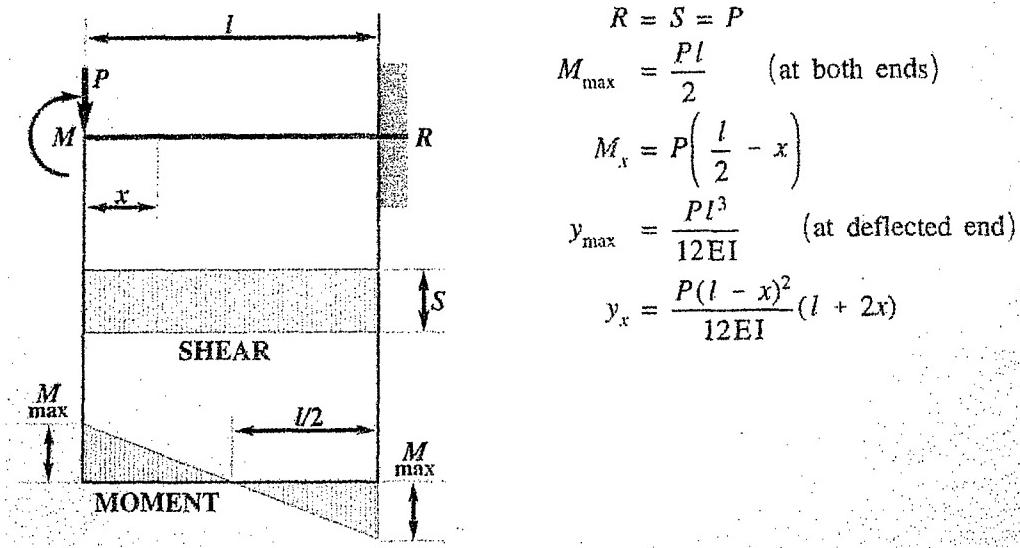
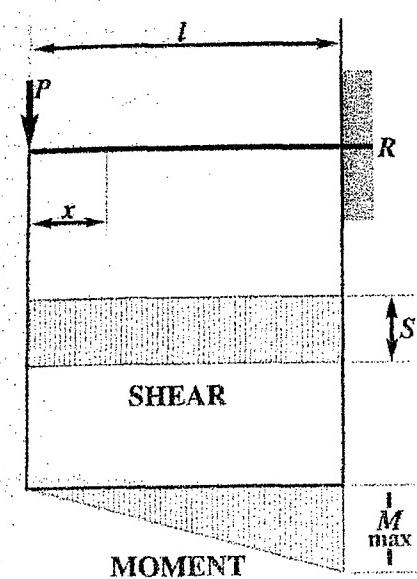


Figure 4.3 Beam fixed at one end and free to deflect vertically, not to rotate

In order to simplify this scenario, the beam length was extended the center of gravity of the hull and transverse load was applied instead of the moment at the free end of the beam (see Figure 4.4).



$$R = S = P$$

$$M_{\text{max}} = Pl \quad (\text{at fixed end})$$

$$M_x = Px$$

$$y_{\text{max}} = \frac{Pl^3}{3EI} \quad (\text{at free end})$$

$$y_x = \frac{P}{6EI}(2l^3 - 3l^2x + x^3)$$

Figure 4.4 Cantilever beam with concentrated load at one end

In order to further develop the load case at the local level between reactions A and B, the cantilever reaction moment is replaced with two reactions as in case of overhanging beam with concentrated load at the end of overhang (see Figure 4.5)

It can be seen immediately that the maximum moment still occurs at the reaction point A. For the reason this section is analyzed in the following section for the occurring stresses at a given point load P. However the bending stresses, or primary behavior stresses, are not the only stresses involved, thus further investigation into local behavior is required. The modeled load case differs from the telescopic beam case, were deflections are restricted. Nonetheless it might be beneficial to look at the behavior of the partially restricted scenario, such as shown in Figure 4.5

The deflections for this case, presented in the Figure 4.6, indicate that the maximum lateral load seen by the top face of the beam, when restricted by the interaction with the hull (see Figure 4.7), exists somewhere between the reaction points, but not at the tip of the beam. This suggests that the loading seen by the interaction area is not as concentrated as it would seem previously, and could be modeled as a distributed area, or line load. At this time it should be noted that as the flanges of the beam experience a lateral loading the plates in the webs experience in-plane loading and should be analyzed for in-plane stresses. However, even if the area distribution was assumed, the transverse

loading the flange would be small compared to in plane loading experienced by the web plates.

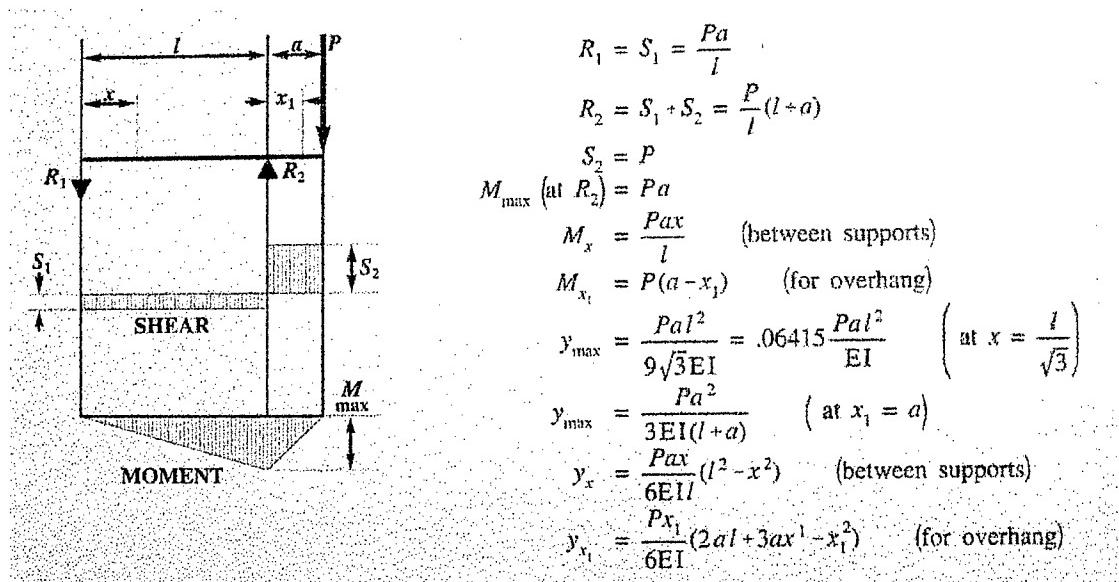
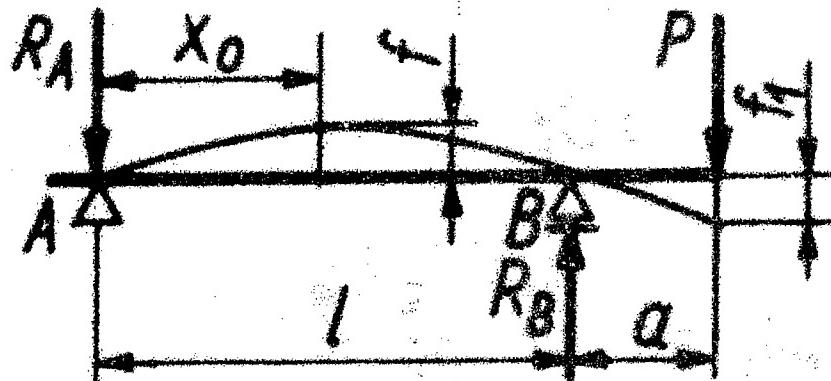


Figure 4.5 Overhanging beam with concentrated load at the end



$$R_A = \frac{Pa}{l}$$

$$R_B = \frac{P(l+a)}{l}$$

$$M_{g\max} = Pa \quad (\text{w B})$$

$$W_z \geq \frac{Pa}{k_B}$$

$$f = \frac{Pl^2a}{9\sqrt{3}EI}$$

$$\alpha_0 = 0,557l$$

$$f_1 = \frac{P(l+a)a^2}{3EI}$$

$$F_{\max} = \frac{W_z k_y}{a}$$

Figure 4.6 Deflections for overhanging beam with concentrated load

The following paragraphs apply this global deflection scenario to substitute concentrated loads with distributed loads. Various distributed loads are considered.



Figure 4.7 Beam Supports

For consideration of this study, the vertical point loads are applied to both faces of the beam. This scenario resembles an end loaded cantilever beam with opposing reactions at a given displacement creating a reactive moment. For theoretical purposes, more appropriate load scenario would be if load q_1 and q_2 were gradually distributed (triangular or parabolic) reactions to the load imposed by the weight of the hull at the opposite end of the girder (see Figure 1.8). Load P is 2.75 [T] (half of the total weight of each hull), and is applied at $x = 2.925$ [m] (girder length, plus half width of the hull, minus 0.2 [m] for girder 'clamping' (distance A-B)).



Figure 4.8 Considered Beam Distributed Loading

Point B is located at $x = 0.2$ [m] and girder is long, $L = 2.5$ [m]. Based on the above information reactions at A and B are determined from force and moment

equilibriums based on sums of the moments and forces. The respective reactions are $R_A = 37.47$ [T], and $R_B = 40.22$ [T]. The resulting simplified uniform loads $q_1 = 7.5$ [T/cm] and $q_2 = 8$ [T/cm], over 0.1 [m] each, are modeled, as presented in Figure 4.9. This lateral loads were obtained by substituting reaction moment from reactions at A and B, by point forces resulting in equivalent moment at the center of the area of the respective distributed lateral loads and distributing those forces uniformly over half span between the reactions.

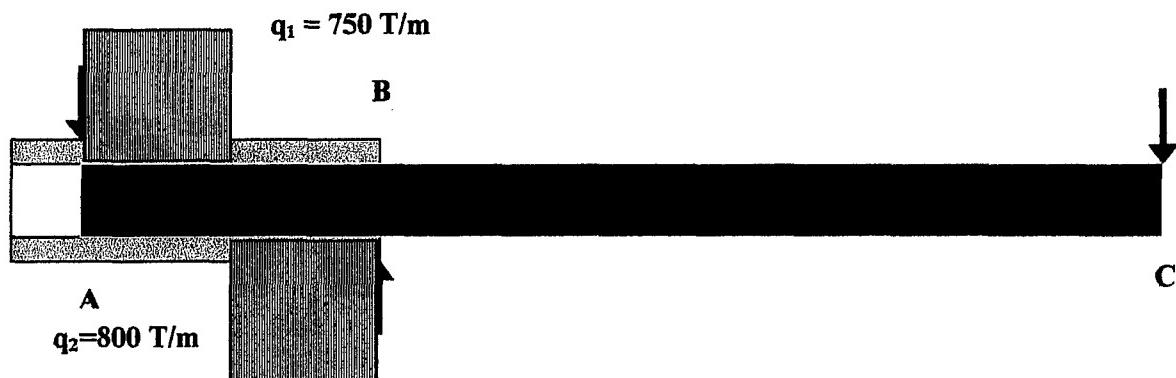


Figure 4.9 Alternative Beam Distributed Loading

The following section will present analysis of the structure leading to determination of adequate stresses in the plates of the girder.

Analytical Method

Two characteristics of the structure are strength to resist encountered stresses and stiffness to resist excessive deflection. To determine above characteristics, one must consider primary, secondary, and tertiary behavior of the members of the structure.

Primary Behavior

In this analysis, the primary stresses and resulting deflections can be determined by applying beam theory to the girder. To find resulting in plane stresses we started with determination of the load and reaction forces. Based on that information stresses can be determined from the following equation:

$$\sigma = M / S \quad (4.1)$$

, where M is the moment at given location x , and S is the section modulus of the girder.

$$S = I / y \quad (4.2)$$

, where y is the distance from the Neutral Axis (NA), and I is the second moment of inertia and $I=2*(a^3 * t / 12 + b * t * (a/2)^2)$ for the analyzed girder.

Based on the above formula, the moment of inertia about NA is $I = 1.35*10^{-4}[\text{m}^4]$. Thus, section modulus is $S = 9*10^{-3}[\text{m}^3]$.

The maximum moment, for point reactions, is at the point x where the shear force is zero. Thus $x = 0.097 [\text{m}]$, and the moment M_{\max} is $36.38 [\text{m} \cdot \text{T}]$. At this point, the axial stress in extreme fibers can be determined, and from equation 4.1 σ is $4 [\text{kgt/mm}^2]$, or $40 [\text{N/mm}^2]$.

Primary stresses are large contributors to total stresses in the critical cross section of the girder.

Secondary Behavior

This approach uses a plate theory to determine corresponding secondary stresses as plates and stiffeners deform between supports under applied lateral loads.

Due to the girder configuration and loading in the zone of maximum bending moment, it can be treated as a short beam (length between points of zero bending moment, $L_o = 0.2 [\text{m}] = b$), and effective breadth is approximately $0.3 * L_o$, or $0.06 [\text{m}]$ (Hughes, 1988). This value could be as high as $0.7 * b = 0.14 [\text{m}]$, but for this analysis a conservative value of effective breadth is selected. In conservative case, the effective section modulus would be $S = 4.8*10^{-4}[\text{m}^3]$, and effectively σ is $75 [\text{kgt/mm}^2]$, or $750 [\text{N/mm}^2]$. For comparison, yield stress for H32 steel is $315 [\text{N/mm}^2]$, and its tensile strength is $470\sim585 [\text{N/mm}^2]$. In this aspect stress in the analyzed girder is very high, but this can be attributed to conservative value of the effective breadth.

Tertiary Behavior

This approach uses an isotropic plate theory to determine corresponding tertiary stresses as plates themselves deform between stiffeners under applied lateral loads.

A rectangular plate is considered of length a , and width b , and thickness t . The equilibrium equations for forces along axis, and corresponding moments are presented in the following equations for small deflection theory.

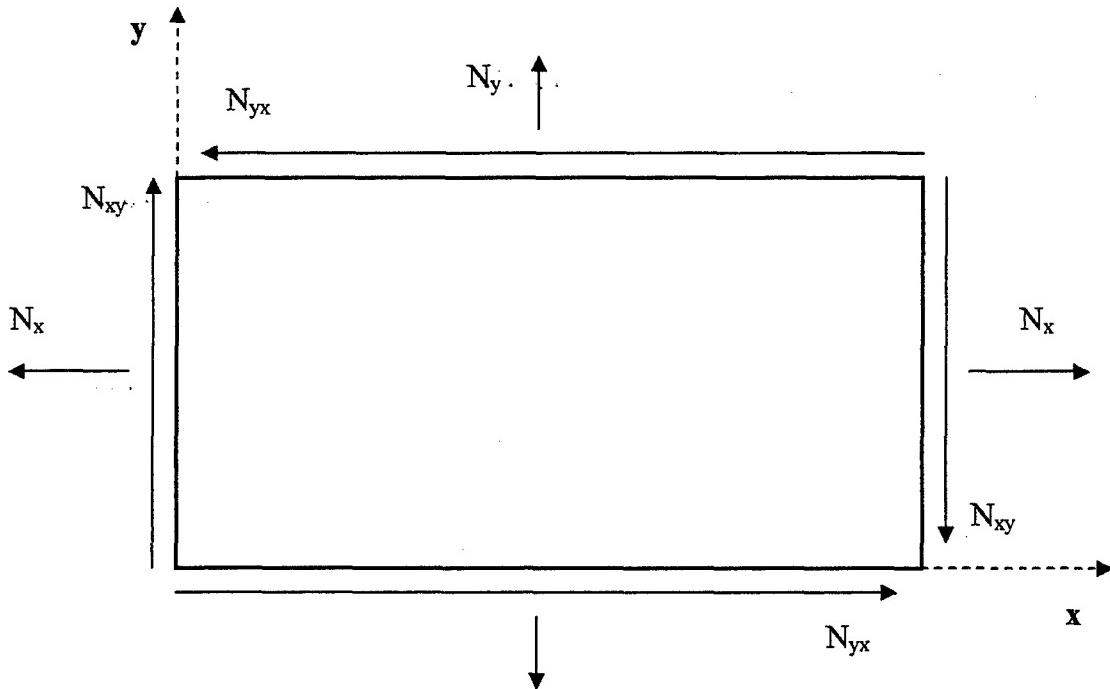


Figure 4.10 Isotropic Plate Configuration

$$\frac{\partial N_x}{\partial x} + \frac{\partial N_{xy}}{\partial x} = 0 \quad (4.3)$$

$$\frac{\partial N_{xy}}{\partial x} + \frac{\partial N_y}{\partial x} = 0 \quad (4.4)$$

$$\frac{\partial M_x}{\partial x^2} - 2 \frac{\partial^2 M_{xy}}{\partial x \partial y} + \frac{\partial^2 M_y}{\partial y^2} = - \left(q + N_x \frac{\partial^2 w}{\partial x^2} + 2N_{xy} \frac{\partial^2 w}{\partial x \partial y} + N_y \frac{\partial^2 w}{\partial y^2} \right) \quad (4.5)$$

After satisfying equilibrium, the strain compatibility has to be satisfied. The following equations present the components of the strain in the middle surface of the plate.

$$\varepsilon_x = \frac{\partial u}{\partial x} = -z \frac{\partial^2 w}{\partial x^2} \quad (4.6)$$

$$\varepsilon_y = \frac{\partial v}{\partial y} = -z \frac{\partial^2 w}{\partial y^2} \quad (4.7)$$

$$\gamma_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} = -2z \frac{\partial^2 w}{\partial x \partial y} \quad (4.8)$$

Material properties link strain tensors and equilibrium forces via Young's modulus E and Poisson's coefficient ν .

$$\varepsilon_x = \frac{1}{tE} (N_x - \nu N_y) \quad (4.9)$$

$$\varepsilon_y = \frac{1}{tE} (N_y - \nu N_x) \quad (4.10)$$

$$\gamma_{xy} = \frac{1}{tG} N_{xy} \quad (4.11)$$

$$G = \frac{E}{2(1+\nu)}$$

where G is the modulus of elasticity.

Strains can be further related to stresses using the Hooke's Law.

$$\sigma_x = \frac{E}{1-\nu^2} (\varepsilon_x + \nu \varepsilon_y) \quad (4.12)$$

$$\sigma_y = \frac{E}{1-\nu^2} (\varepsilon_y + \nu \varepsilon_x) \quad (4.13)$$

$$\tau_{xy} = G \gamma_{xy} \quad (4.14)$$

Ultimately, the stresses can be related to displacements by following substitution.

$$\sigma_x = -\frac{Ez}{1-\nu^2} \left(\frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial y^2} \right) \quad (4.15)$$

$$\sigma_y = -\frac{Ez}{1-\nu^2} \left(\frac{\partial^2 w}{\partial y^2} + \nu \frac{\partial^2 w}{\partial x^2} \right) \quad (4.16)$$

$$\tau_{xy} = -2zG \frac{\partial^2 w}{\partial x \partial y} \quad (4.17)$$

Eventually, moments can be related to displacements by substituting above stresses into:

$$M_x = \int_{-h/2}^{h/2} z \sigma_x dz \quad (4.18)$$

Similarly for M_y and M_{xy} .

$$M_x = -D \left(\frac{\partial^2 w}{\partial x^2} + \nu \frac{\partial^2 w}{\partial y^2} \right) \quad (4.19)$$

$$D = \frac{Et^3}{12(1-\nu^2)}$$

, where

Shear Distribution

The maximum shear force $Q = 40$ [T], occurs in cross section at $x = 0.2$, or point B and maximum shear stress at that section can be determined by first calculating a shear flow in the beam at the Neutral Axis (NA).

$$q = Q * m/I \quad (4.20)$$

, where

$$m = \int y * t * ds \quad (4.21)$$

Thus, $m = (a/2 * t * b/2) + (a/2)^2/2 * t$, or $m = 1.275 * 10^{-4}$ [m³], and $q = 37.78$ [T/m]. Effectively, the shear stress is obtained by dividing shear flow q by the actual thickness of the web, thus $\tau = 3.8$ [kgf/mm²], or 38 [N/mm²].

The following section discusses additional steps required for the structural design analysis, evaluation, and structure optimization.

Findings

The above analysis considered the three key elements contributing to the total stresses in the structural system. Stresses resulting from the primary structure behavior are the major contributors, however secondary and tertiary behavior influence stress distributing and contribute considerably to total stress.

The distributed loading in presented above case, poses several problems as in-plane and transverse loads are involved simultaneously. Methods such as Finite Element Analysis could prove very helpful in local stress evaluation, assuming proper loading is applied. The modes of buckling and buckling critical loads would contribute further to the knowledge of the structure behavior under scrutinized conditions. In particular, the beam's web plate at the cross section with large in-plane loading should be further analyzed. The configuration of the considered structure suggests susceptibility to torsion at global and local levels, thus torsional rigidity should be also considered.

The primary loading and corresponding stresses were determined, but further investigation should evaluate optimized scenarios, which should streamline the structure due to less conservative approach.

The finite element analysis, evaluation, and optimization based on MAESTRO Version 8.0 software, the Structural Design System, was considered in this project, but final results were not obtained at this time.

Assumptions

- Small deflections are assumed
- Small plate thickness compared to other dimensions
- Linear plastic material

Limitations

- Complicated lateral load distribution along the boundaries
- Difficulties in determining precise loads dictate conservative load assumption
- Dynamic loads were not considered
- Buckling was not evaluated
- Torsional rigidity was not evaluated
- Additional axial loads in the beam were not considered

Recommendations

The load factor, distribution, is considered as a simplified configuration in form of uniform load, possibly resulting in biased analysis. Modifying the load distribution in more sophisticated fashion shall deliver more precise results, but applying discussed uniform distribution is simple and might prove adequate upon further analysis such FEM and experimental methods. In addition to conversion of the concentrated reactions to distributed load, a cargo distributed and concentrated loads should be analyzed and superposed stresses evaluated.

Foremost, further investigation shall be considered to analyze dynamic loading, as well as influence of loads along beam's longitudinal axis and torsion.

Secondly, the conclusions of this study should be verified using other analytical and finite element methods.

DPCAT Resistance and Power Calculations and Comparisons

The resistance and power required for DPCAT was calculated using same AUTOPOWER program as for the case of LARC V and modified LARC, however catamaran hull method was employed versus displacement methods.

The Compton Semi-Displacement, Savitsky's Planning, and FastCat Catamaran methods were utilized for better evaluation. Results are presented in the Appendix 12. Not surprisingly, for different hull types the resistance and ultimately effective power varied. Interestingly, the semi-displacement method effective power prediction closely follows the empirical results for the respective Froude number range. Steep increase take place upon reaching Froude number 0.42, as predicted in earlier discussion within the background section.

In case of planning hull assumption, effective power requirements are quite smaller, and allow reaching much larger Froude number within reasonable amount of power. This method, not surprisingly, also indicates the hump at about 19 Knots, or Fn 0.99. The local minimum follows at approximately 20 Knots, suggesting a choice of the service speed for this scenario. Assuming available power from the MTVR engine of 425 [HP], approximately 350 [kW], maximum speed between 20 and 30 Knots could be achieved.

In case of the FastCat Method for the Catamaran, various modifications were required in order to arrive at satisfactory approximate results. In order to achieve a proper displacement to length ratio, required for this method, the displacement and length had to be slightly modified. The modification closest to the real scenario, with displacement of 10.5 [T] and Length on Waterline (LWL) of 12.5 [m], proved to be satisfactory for the method. The results indicated that with 350 [HP], effective, maximum speed of 25 Knots can be achieved. This necessary adjustment indicates that some adjustments to the model might require decrease in displacement, or hull extension of approximately 20% on waterline. Various scenarios were also analyzed, where displacement was held constant with varying LWL, ad vice versa. Results are presented in Appendix 12. It indicates that, in order to maintain displacement of 17 [T], LWL would have to be increased to 14.75 [m] at similar effective power. The opposite

scenario proved less beneficial as lower speed with similar amount of effective power can be achieved. The above evaluations shall be verified using methods, which will allow resistance and effective power evaluation at displacement of 11 [T] with 9.88 [m] LWL. Nonetheless, the above evaluation allowed some preliminary and approximate estimate for various concepts of hulls, including semi-displacement, planning, and most appropriate for this study catamaran.

Main engines can be determined based on the results of previous studies, which should be verified by the empirical tests. The amount of fuel required can be estimated based on operational parameters and the selected engines.

The results and evaluations of the resistance and effective power calculations are presented in Appendix 12.

Chapter 5. CONCLUSIONS

Based on the preceding background information the main factors of the technical approach within the scope of this project are improving the stability and the waterborne speed through hull redesign or modifications and increased shaft power along with propulsion efficiency.

Summary and Recommendations

One of the major factors limiting the original vessel's performance in the water is frontal area described in large by the wheel signatures (see Fig.3 appendix 3). In order to mitigate this problem some kind of wheel encapsulation is required. This might not be feasible as long as the wheels remain the steering wheels. Thus, one option to look into might be reversing the direction of movement of the vehicle, where stern wheels would be steering wheels and front wheels could be partially encapsulated in this case. Good example here is the LARC X, formerly used by the UCT (see Fig.10 in appendix 4). In addition, some kind of underbody and perhaps bow plane might have to be used to achieve a significant increase in speed; such as was done in case of AAAV (see Fig.9 in appendix 4).

Another factor limiting the waterborne performance is constrained propeller's ground clearance (see Fig.4 and 5 in Appendix 3). The size of the propeller can not be increased in this case and, as indicated in the JJMA report of study of the propeller [Ref.3], large increase in efficiency or shaft power would be required for small increase in speed. The option is to look into the high power water jets and the high power density propulsion.

The dual hull configuration of DPCAT creates an opportunity for satisfying the owner's requirement for the Boat Deployment System. Deployable small boat aboard the vehicle is essential to the success of many UCT's seagoing missions. System that deploys Zodiac boats via integrally designed stern ramps is used worldwide on larger vessels and should be considered in the new design of the dive platform. Some suggested here types of recovery systems are shaped or flat hinged ramps, fixed ramps, extended

ramps. Number of criteria must be considered in such developments, such as deployment, stern-ramp motions, ramp availability, and obviously deployable boat criteria [ref.12]. In any case, the coxswain's skills are critical in this difficult operation as roll, pitch, heave, yaw, and sway accelerations develop; thus limiting ramp availability.

Beside highway compliance, another critical owner's requirement will be satisfied with dual hull design, as it will also increase (double) the work deck area as beam extends during the waterborne operations. Increased stability of demi-hulls must be mentioned here as well. In addition to catamaran, another potential contender is SWATH vessel, due to its superlative seakeeping in rough seas, stability, and resistance reduction characteristics. However, the draft (hull submergence) and load capability due to small waterplane area hulls have its down side in limited load variation; unless sophisticated ballast system is provided [Ref. 13]. Nonetheless, it should be considered in further studies as an alternative to catamaran concept.

The demi-hulls usually lead to added weight due to duplicate machinery and structure. However, this could be minimized by outfitting the vessel with innovative electric propulsion.

In summary, preliminary findings based on the visit to UCT2 and UCT1 and on the literary review were discussed. Selected owner's requirements were listed, hull fairing and choice of the propulsion system were analyzed and discussed. It is intended that further studies will continue, and will concentrate on tradeoff studies of choice of the optimal hull form and choice of the optimal propulsion system, where in addition to speed, the increased power and the water jets might contribute to improved maneuverability and ultimately stability in the surf zone. Further studies are required to develop hull forms and corresponding propulsion as presented in Appendix 1.

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REFERENCES

1. U.S. Marine Corps, FMFM 9-2 Amphibious Vehicles 1981
2. Society of Automotive Engineers, Inc., SP-261 Mobility of Terrain – Vehicle Systems, Optimization of Design and Performance, 1964
3. Dize A. P., John J. McMullen Associates, Inc., Lighter, Amphibious, Re-supply, Cargo, 5-Ton (LARC-V) – Product Improvement Study, September 1999
4. FAS Military Analysis Network, Advanced Amphibious Assault Vehicle, <http://www.fas.org/man/dod-101/sys/land/aaav.htm>
5. Mandel P., Water, Air and Interface Vehicles, The M.I.T. Press, 1969
6. Bailey A. D., Alligators, Buffaloes, and Bushmasters, History and Museum Division Headquarters, U.S. Marine Corps Washington, D.C., 1986
7. Woodtech U.K. Vehicles, Amphibious Vehicle, http://www.woodtech.force9.co.uk/larc_v.htm
8. LARC Description, <http://www.globalsecurity.org/military/systems/ship/larc.htm>
9. U.S. Marine Corps, <http://hqinet001.hqmc.usmc.mil/>
10. Discussions and e-mails from UCT2 personnel and management
11. Chun H. H., Kim M.C., Ahn B.H., Cha S.M., Self-Propulsion Test and Analysis of an Amphibious Tracked Vehicle with Waterjet, SNAME Annual Meeting Paper, 2003
12. Sheinberg R., Minnick P., Beukema T., Kauczynski W., Silver A., Cleary C., Stern Boat Deployment Systems and Operability, SNAME Annual Meeting Paper, 2003
13. Murthy T., Brebbia C., Topics in Engineering - Marine Engineering, Computational Mechanics Publications Southampton UK and USA, 1994
14. Keh-Sik Min, Seon-Hyung Kang, Oi-Hyun Kim, Conceptual Design of Very Large-Size Super-High-Speed Foil Catamaran Containership, SNAME Annual Meeting Paper, 2003
15. AUTOSHIP User's Manual
16. AUTOPOWER User's Manual
17. ME 240B, Advanced Marine Structures, Class Material, UC Berkeley Fall 2004

18. Faltinsen, O.M., Sea loads on ships and Offshore Structures, 1990
19. Hughes, O., AOE 4274, The MAESTRO Structural Design System – Method For Analysis, Evaluation, and Structural Optimization, Version 8.0, Virginia Polytechnic Institute and State University Printing Services, Spring 2000
20. Hughes, O., Ship Structural Design, SNAME 1988
21. Mansour , Alaa 2003, Ultimate Compressive Strength of Imperfect Unstiffened Plates: Simple Design Equations, Journal of Ship Research, SNAME 2004
22. ME 240B, Advanced Marine Structures I Class Notes, Fall 2004
23. Principles of Naval Architecture, SNAME Volume I, 1988
24. Timoshenko, S. , Theory of Plates and Shells, McGraw-Hill 1940
25. Johnson E., Hughes O., AOE 3024 Thin-Walled Structures, Virginia Polytechnic Institute and State University Printing Services, Spring 1998
26. ASNE & JMS, Inc., Marine Casualty Response: Salvage Engineering, Kendall/Hunt 1994
27. Poradnik Mechanika, Volume 1, Wydawnictwa Naukowo – Techniczne 1988

APPENDICES

Appendix 1. Vessel Design Elements

Design requirements Study Program, bold items discussed and underlined items discussed in more detail in the report (does not include automotive portion of the design; should be intertwined along the vessel design phases). Vessel Design Process:

- a. **Demonstrate understanding of the Owner's Requirements**
- b. **Technical approach, trade off studies and alternative solutions**
- c. **Technical Risks and means to alleviate**
- d. **Table of Principle Characteristics**
- e. **Weight Estimate LightShip**
- f. **Weight Estimate Full Load at Departure**
- g. **Curves of Form**
- h. Floodable Length Curve
- i. Trim and Intact Stability
- j. Damage Stability Analyses
- k. **Lines Drawing**
 - l. Inboard Profile and Deck
 - m. Arrangements
 - n. Capacity Plan
 - o. Machinery Arrangements
- p. **Structural Midship Section**
- q. **Speed/power analysis**
- r. Electrical Load Analysis
- s. Seakeeping Analysis
- t. **Area/Volume Summary**
- u. Manning Estimate
- v. Major HM&E
- w. **Propulsion Plant Trade-off Study**
- x. Endurance Fuel Calculation
- y. Cost Analysis
- z. Technical Risk Summary

Appendix 2. Medium Tactical Vehicle Replacement (MTVR)



Figure A2.1. Medium Tactical Vehicle Replacement (MTVR)[ref. 9]

The MTVR program replaces the aging M939/M809 5-ton trucks with a fleet of state-of-the art, commercially based, medium trucks with greater mobility, lift, and reliability. The MTVR has an increased payload of 7.1 tons cross-country and 15 tons on hard surface roads and can simultaneously tow an 11 ton load. The MTVR has a 70 percent off road and 30 percent on road mission profile and is capable of sustained speeds of 30 mph cross-country. Commercial components include: 425 horse power electronically controlled engine; seven speed, continuous power, automatic transmission; 6-wheel independent suspension; anti-lock brakes; engine retarder (“jake brake”); automatic traction control; and central tire inflation.

The standard cargo variant's weight 28,000 pounds and has a reducible height of 98 inches, which makes it internally transportable by KC-130 and externally by CH-3E.

Developer/Manufacturer

Oshkosh Truck Corporation, Oshkosh, WI

Appendix 3. LARC V Photos

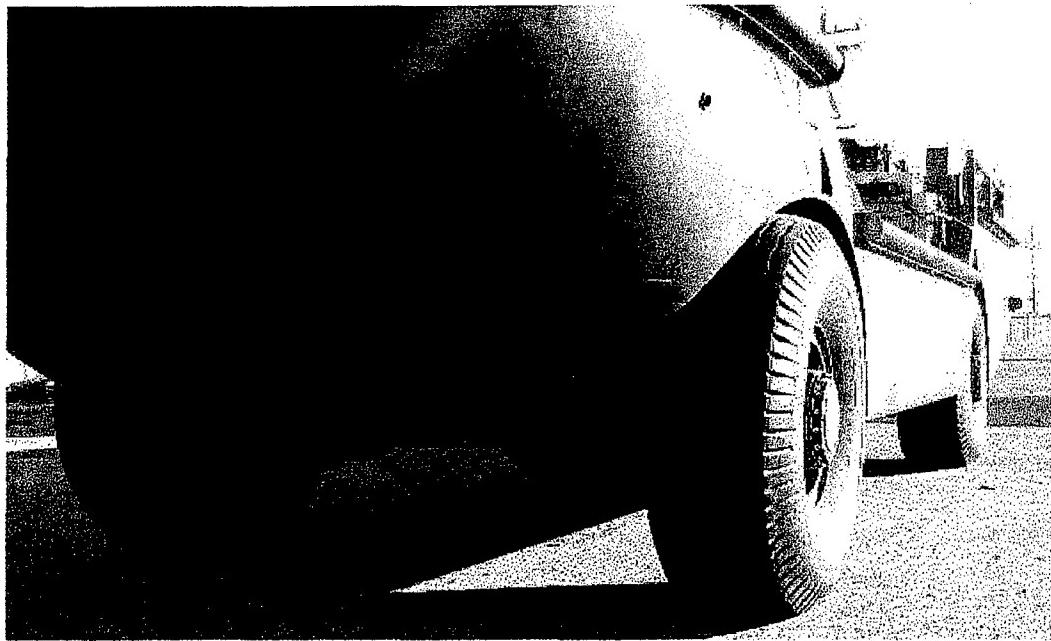


Figure A3.1. LARC V's Frontal Transverse Area

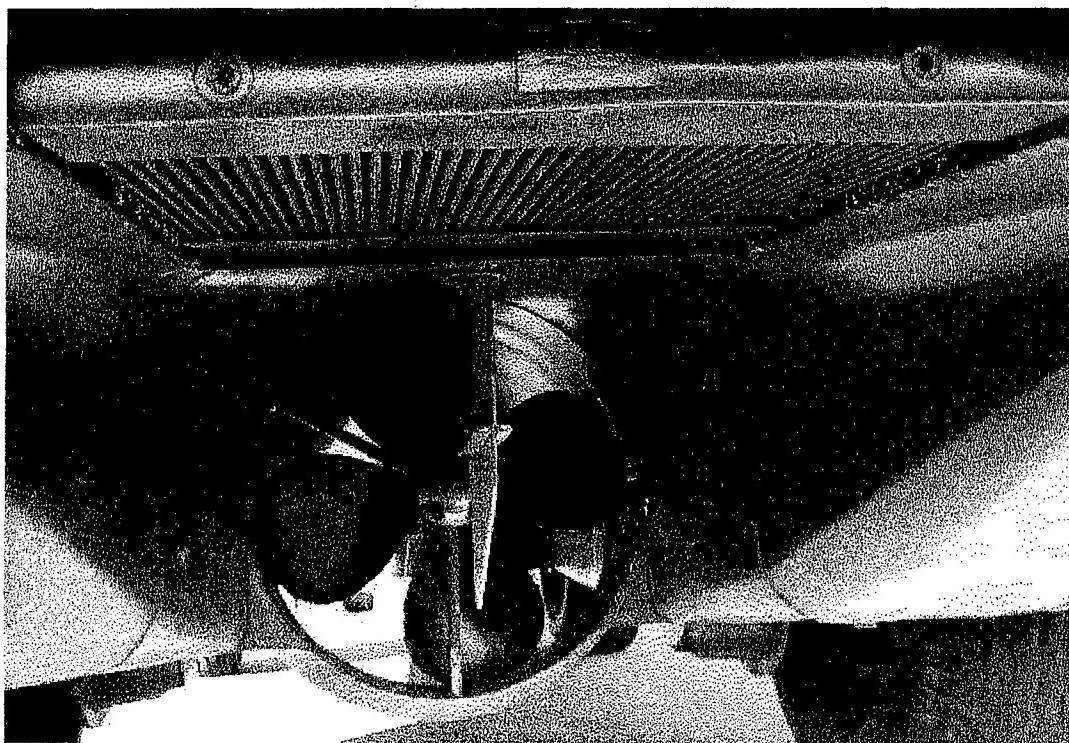


Figure A3.2. LARC V Propeller and Ground Clearance

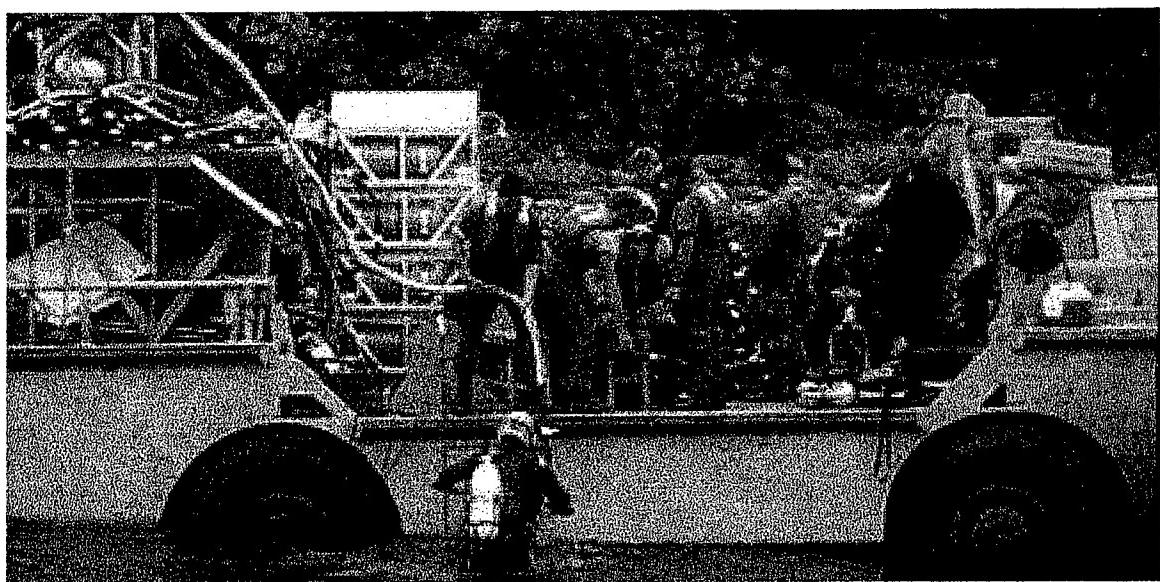


Figure A3.3. LARC V's Deck Cluster during Dive Operations



Figure A3.4. LARC V Waterborne on 18 December, 2003

Appendix 4. Alternative Vehicles (AAAV, LARV X)

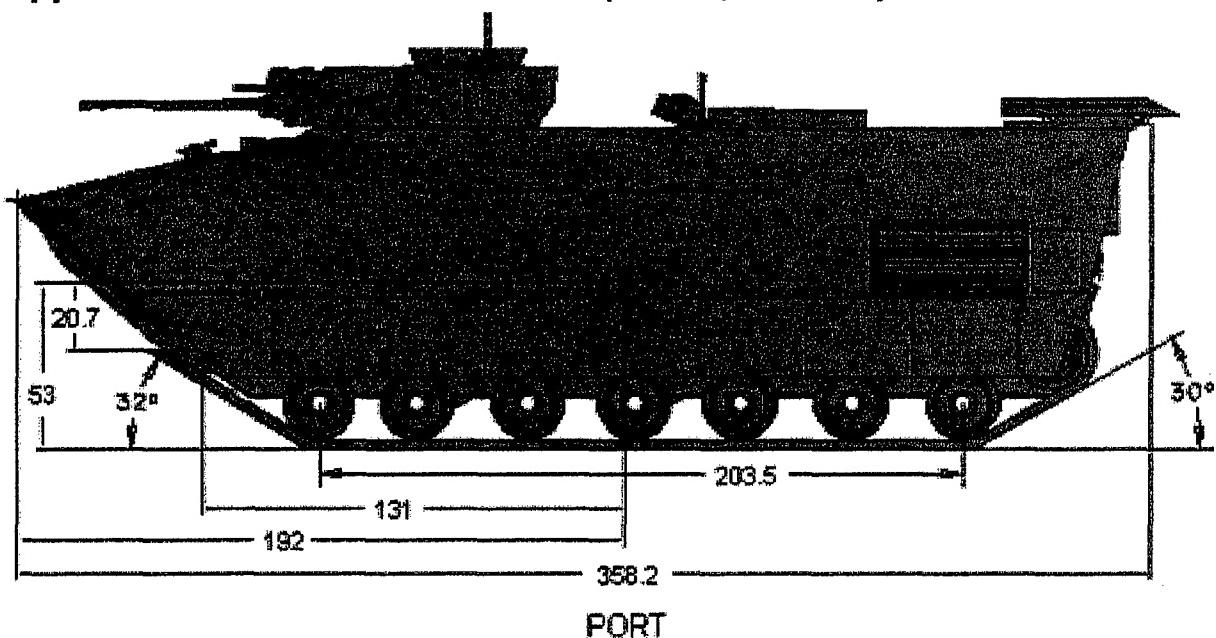


Figure A4.1. Marine Corps AAAV port dimensions [ref.4]

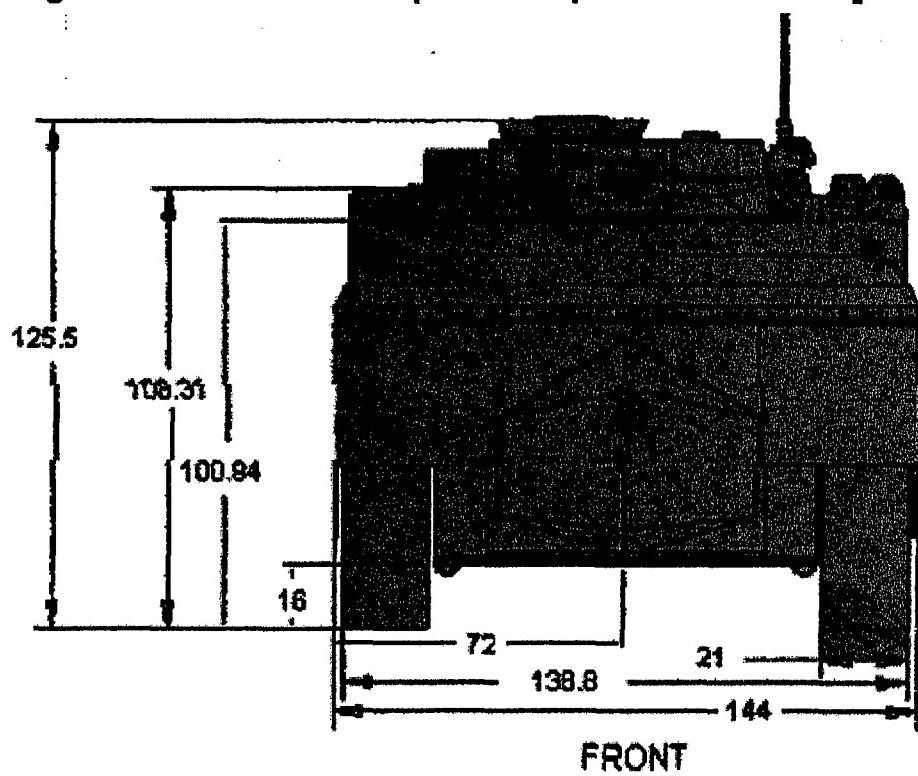


Figure A4.2. Marine Corps AAAV Frontal Dimensions

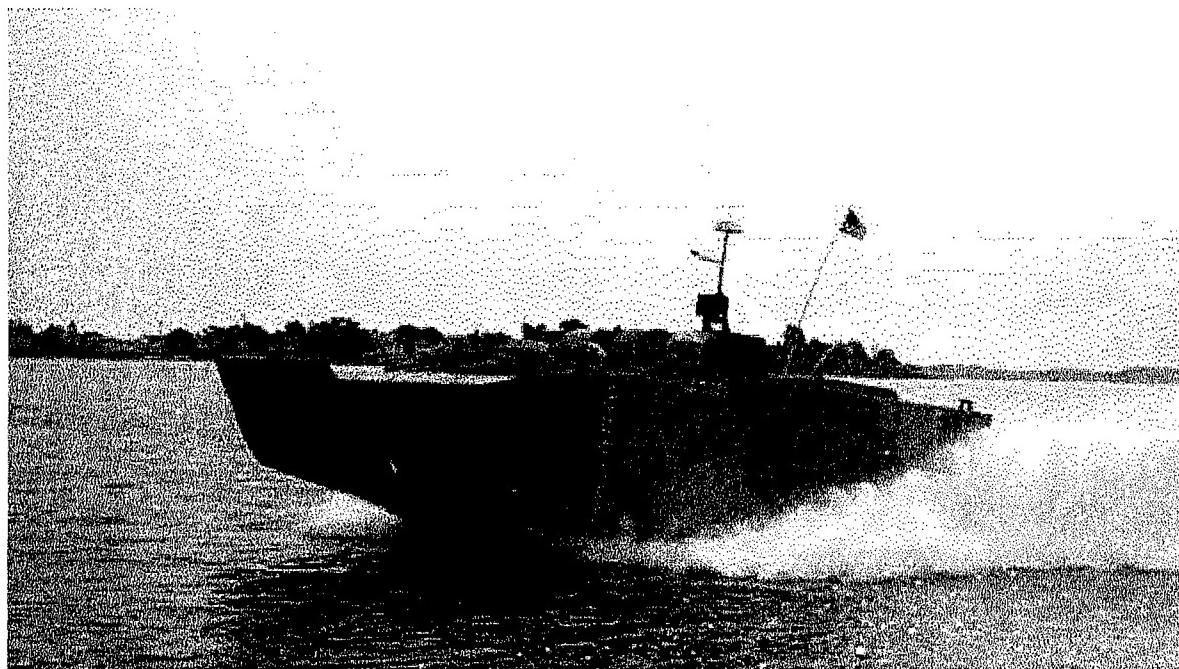


Figure A4.3. Marine Corps AAV Planning Speed with Bow Plane
[ref.4]

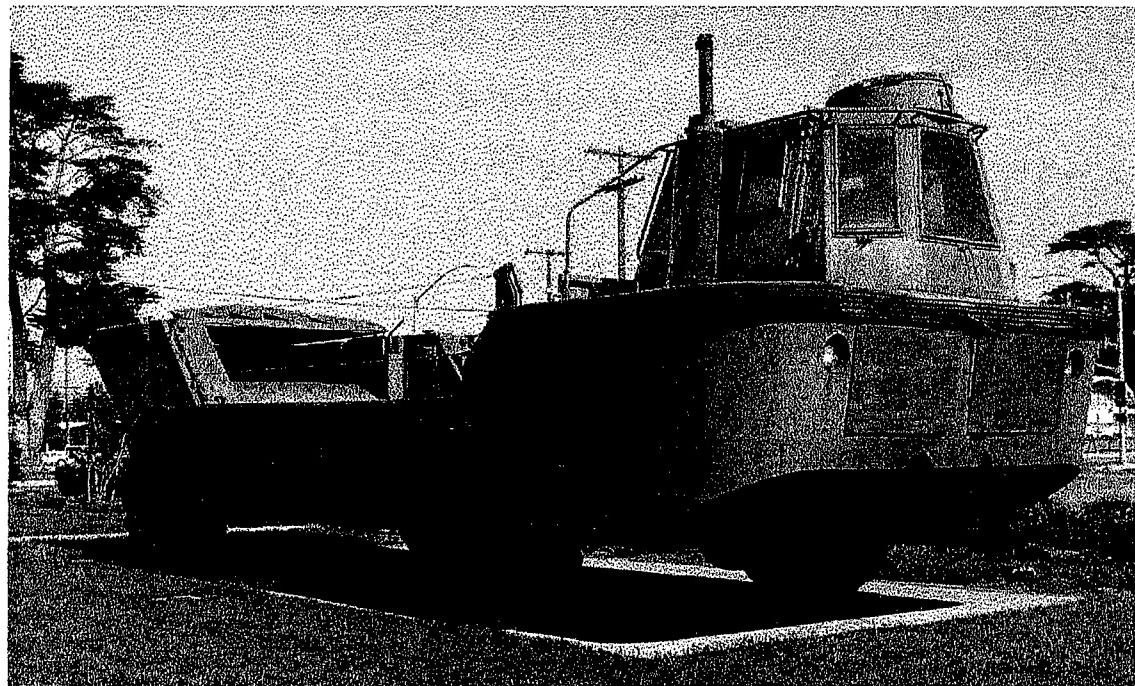


Figure A4.4. Former UCT2 LARC X

Appendix 5. LARC V and AAAV Comparison Table

		MTVR engine			
		Parameter	AAAV	LARC	LARC imp
Power, [hp]	Land-2600rpm		850	295	425
	Sea-3300rpm		2,575	295	(1037)*
	Weight, [lbs]		74,500	30,000	30,000
Power/Weight	Sea-3300rpm		0.035	0.010	0.014
		Parameter	AAAV	LARC	
Size:	Length, [ft]		29.85	35	
	Width, [ft]		12	10	
	Hight, [ft]		10.45	10.2	
Freeboard	loaded [in]		15	10	
Draft (approx.)	loaded [ft]		7	4	
Clearance	[ft]		1.3	1.3	
Cargo	[lbs]		5,000	5,000	
Speed (listed)	Land, [MPH]		45	30	
	Sea, [knots]		25	9.5	
Range	Land	300 [miles]	200 [nm]		
	Sea	65 [nm]	40 [nm]		
Transverse A _T	[ft ²]		84	40	

Required power upper bound: (1037)* [hp]

Required power 'lower' bound: 494 [hp]

Table A5.1. Parametric Characteristics of LARC V versus AAAV

Appendix 6. AUTOSHIP Models of LARC V and Modified LARC

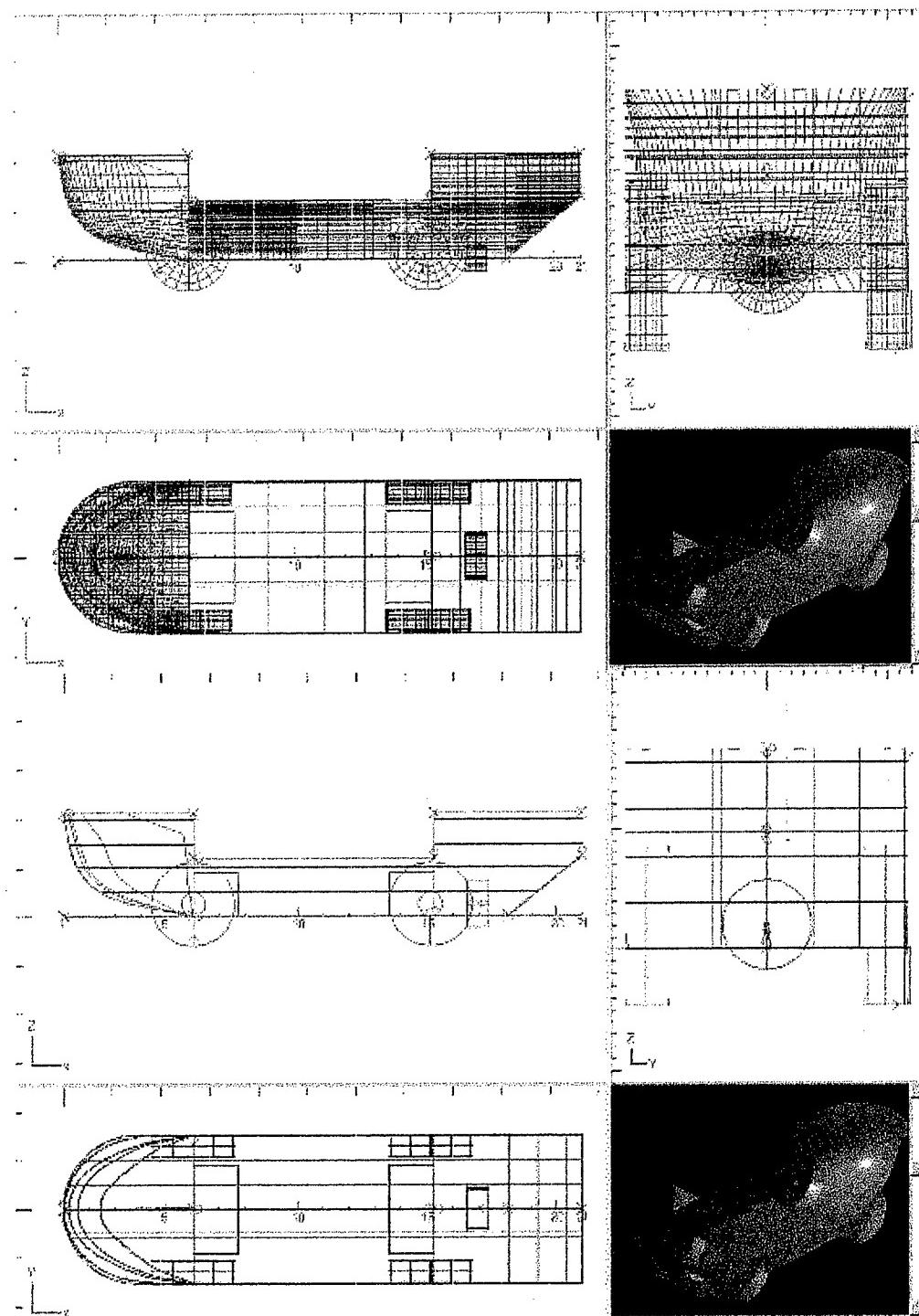


Figure A6.1. LARC V AUTOSHIP Model and Offsets Lines

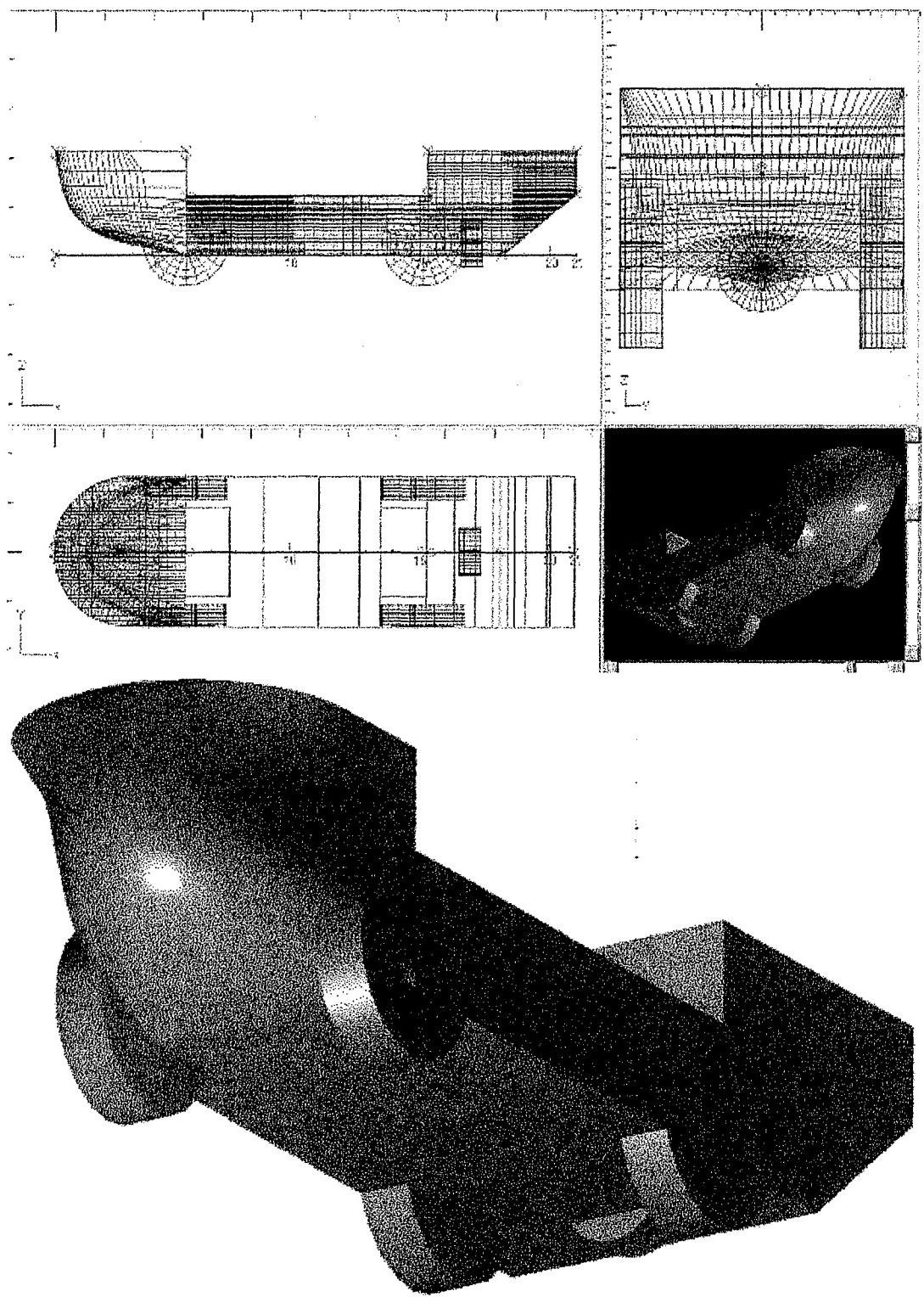


Figure A6.2. LARC V AUTOSHIP Model and Contour Lines

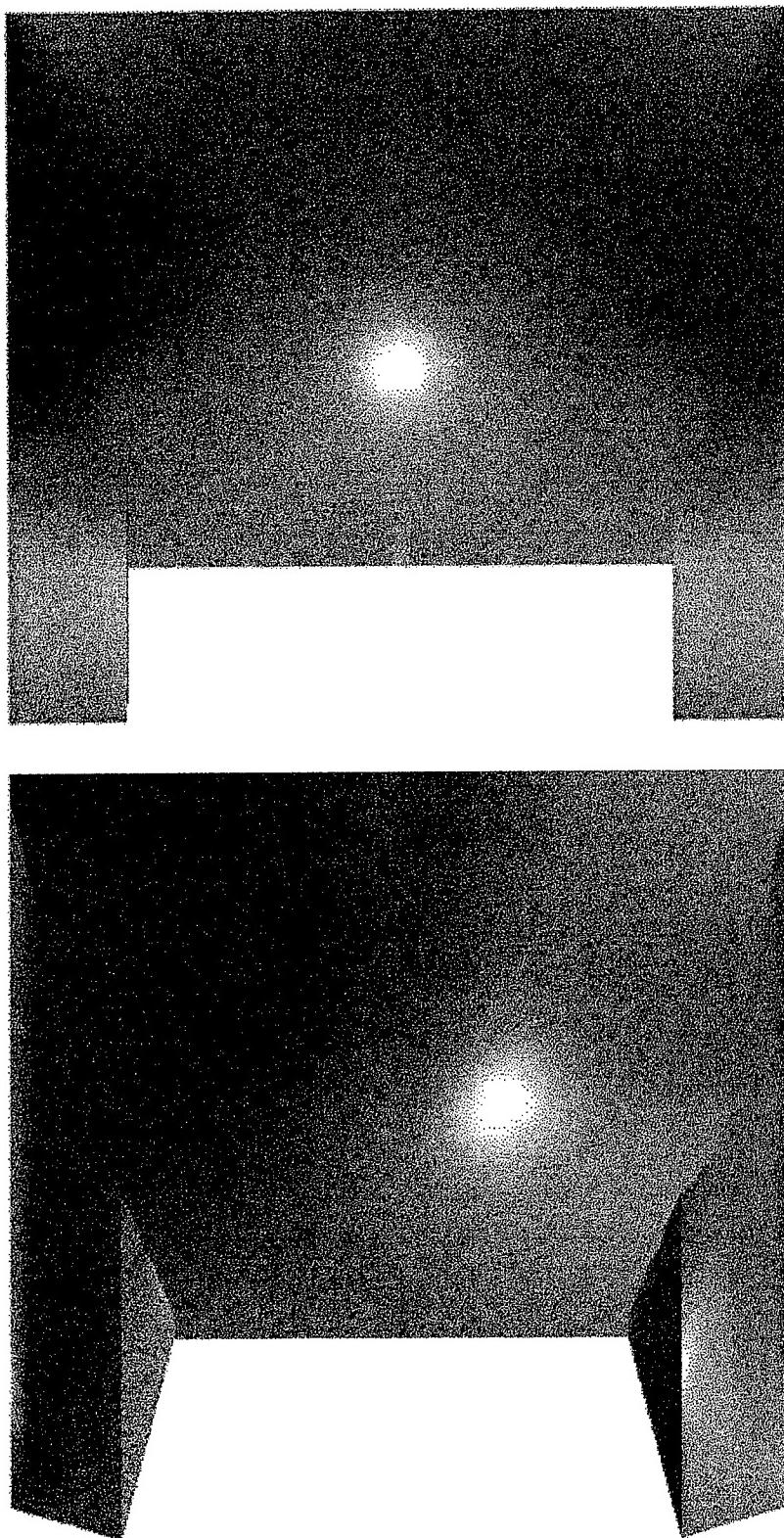


Figure A6.3. LARC V AUTOSHIP Model versus Modified LARC

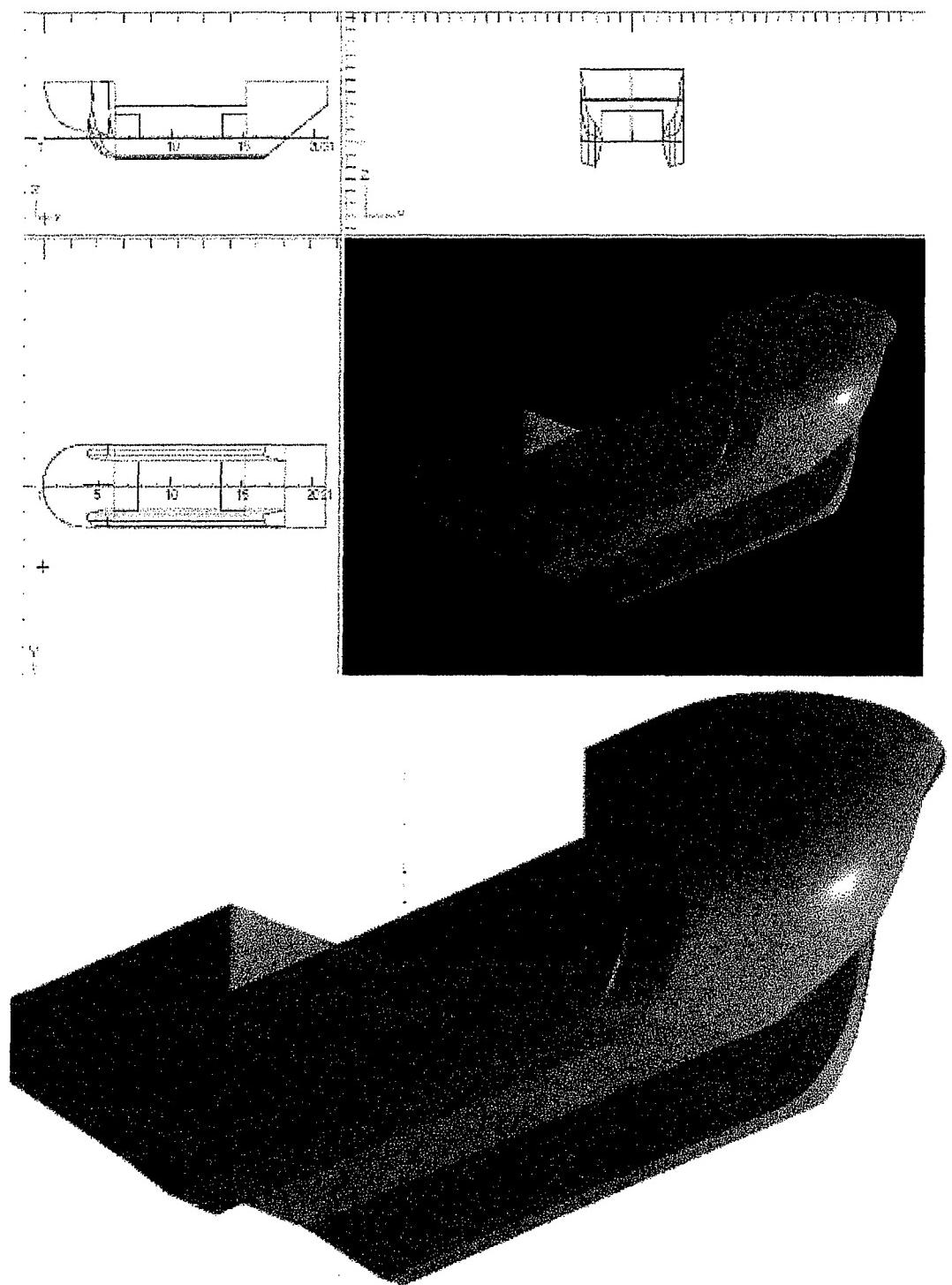


Figure A6.4. Modified LARC Model

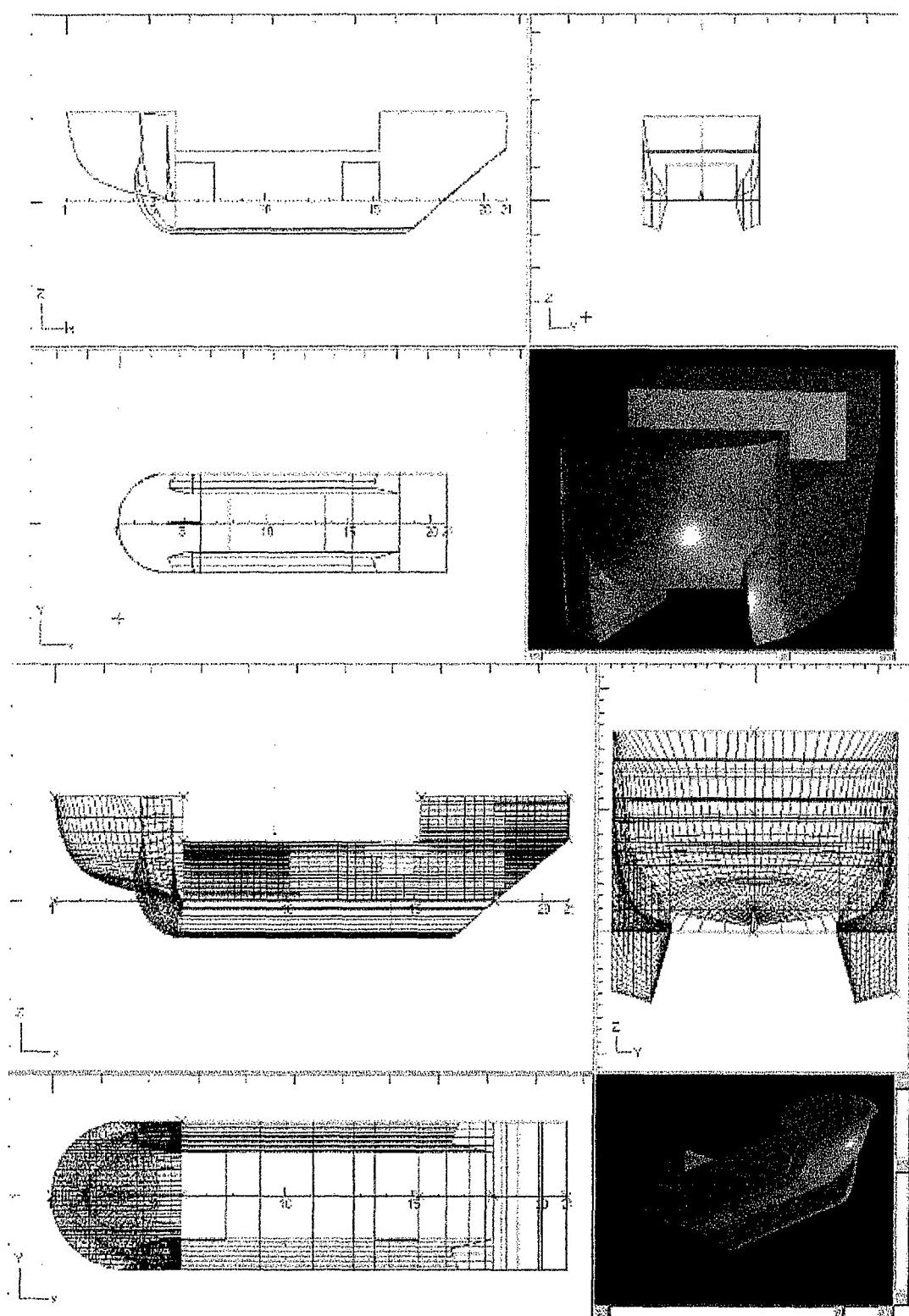
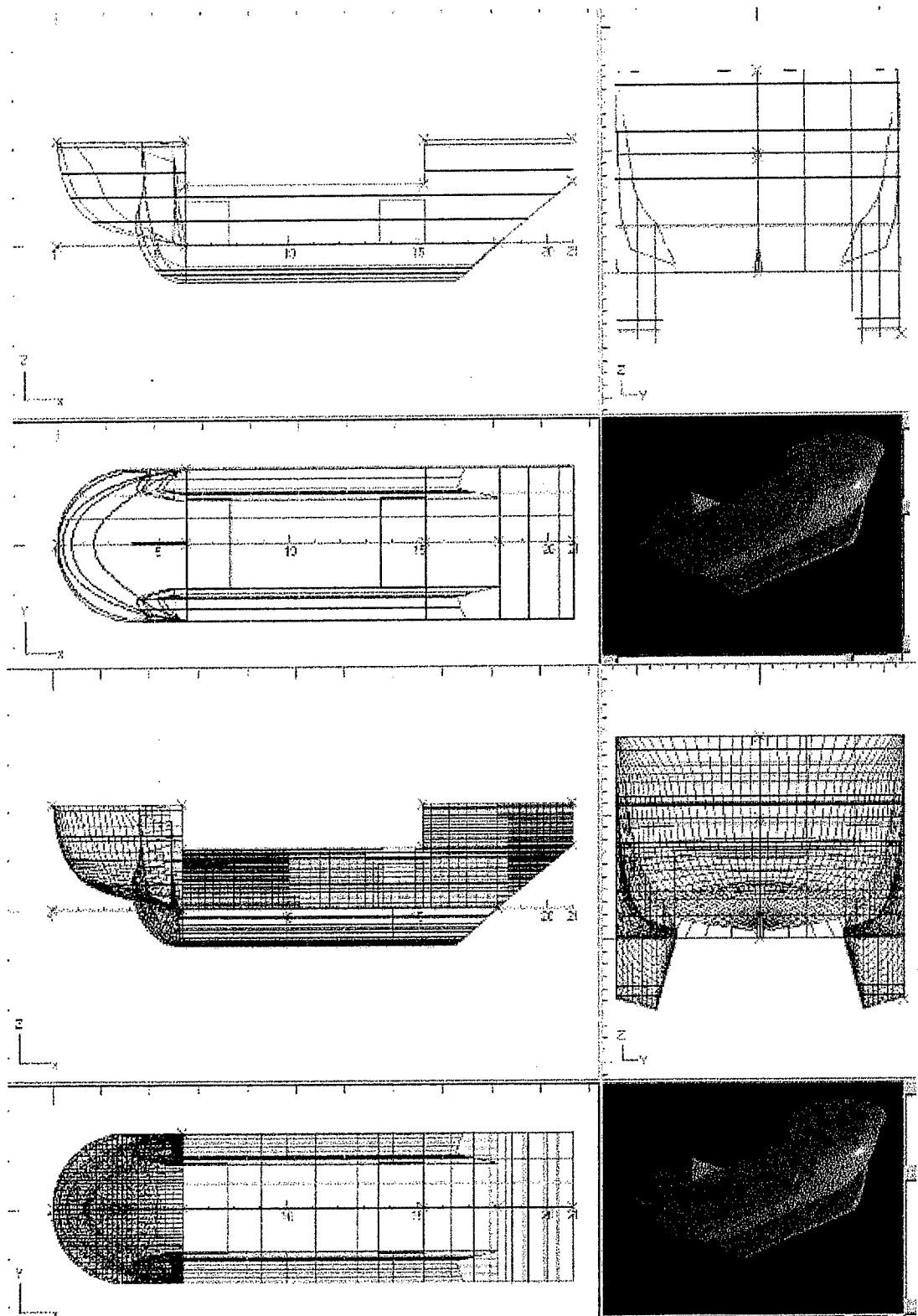


Figure A6.5. Modified LARC Model and Contour Lines



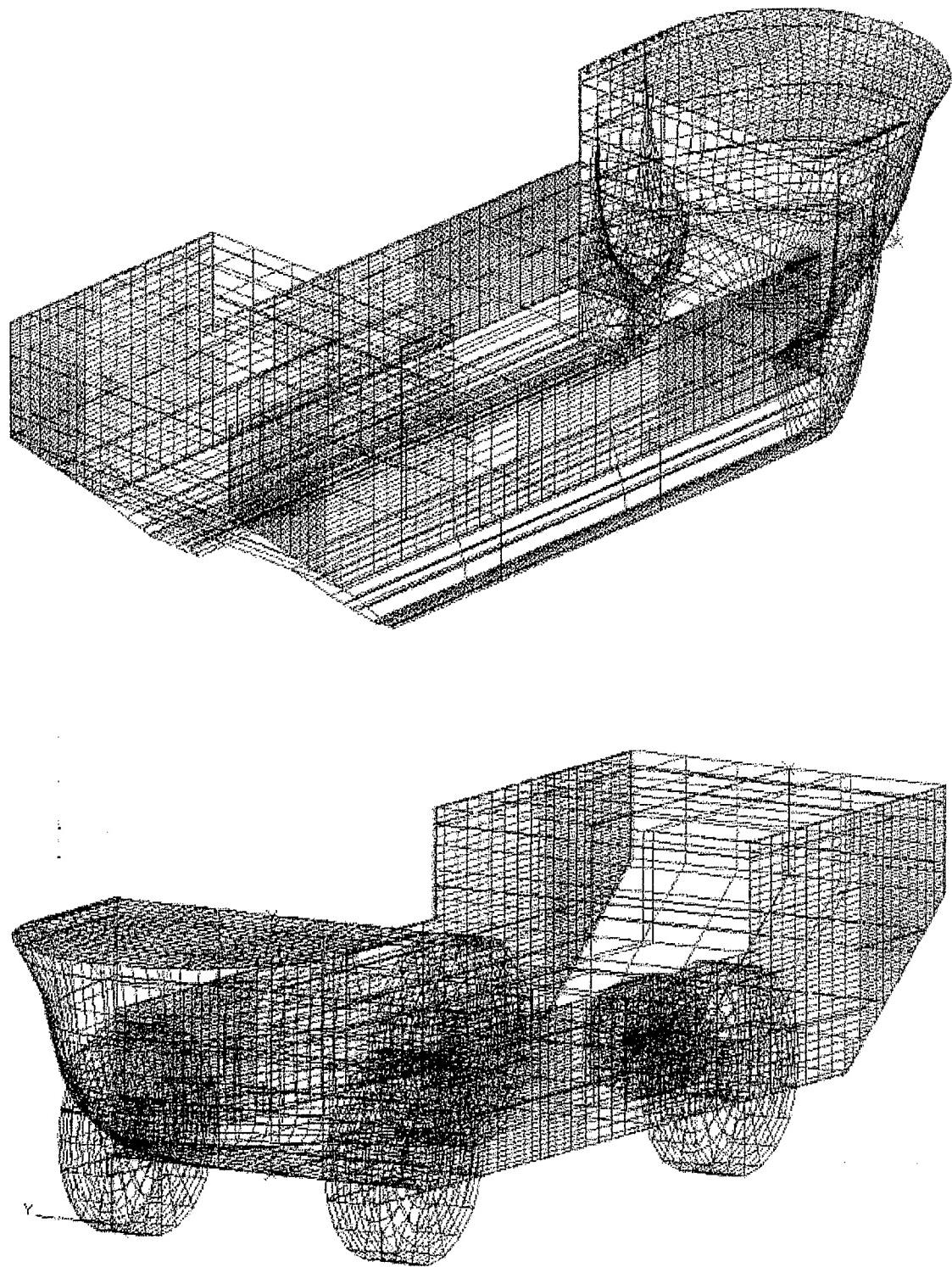


Figure A6.7. Contour Lines of LARC V and Modified LARC Models

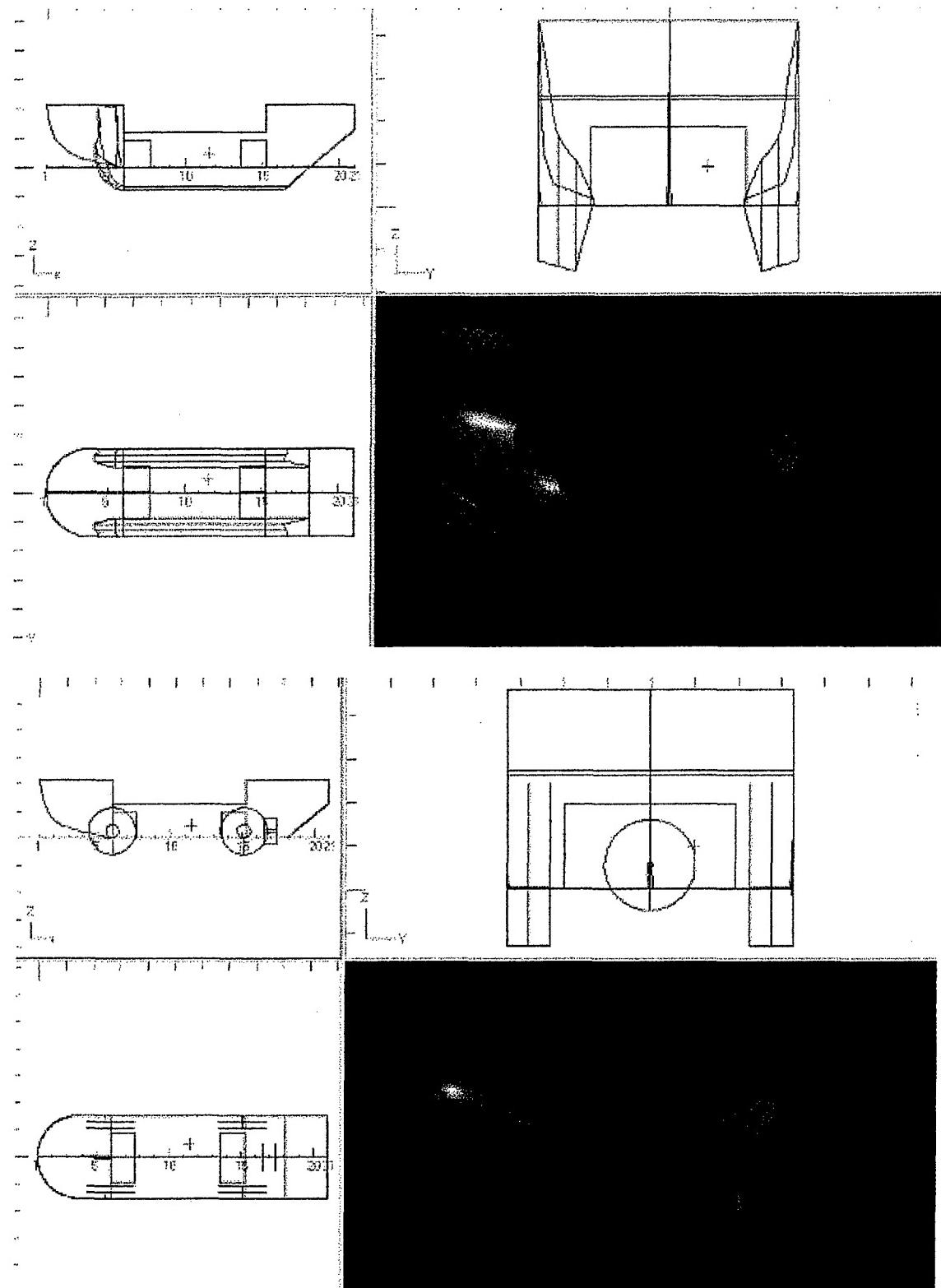


Figure A6.8. AUTOSHIP Models of LARC V versus Modified LARC (1)

Appendix 7. LARCs' Resistance & Effective Power Calculations

Displacement	R	P	L	Calcs
Project Name:				LARC1
Length (L)	9.88	9.88		
Draught (D)	3.05	3.05		
Draft (d)	0.90	1.00		
Draft (k)	0.90	1.00		
Displacement	23.18	22.38		
HB	6.40	6.59		
FWR	0.77	0.64		
EN	0.88	0.75		
Form Factor				
Projected Hull Area	92.20	99.46		
Projected Waterline Area				
Projected Bottom Area				
Projected Hold	3.05	3.05		
Total Angle of Side				
Total Angle of Hull				
Wetted Surface Area				
Bottom Centerline Location				
Body Type (F)	U	U		
Body Type (A)	U	U		
Stability Margin				
Expendage Allowance				
Expendage Form Factor				
CB	0.83	0.72		
CP	0.95	0.97		

Table A7.1. AUTOSHIP Resistance and Effective Power Calculation Input

Fung and Holtrop Methods for Displacement Hull using Holtrop/Mennen wetted surface area

Resistance and Power Prediction from AutoPower V3.0.0

Project: LARC1
 Date: 11 Oct 04
 Hull Type: Displacement

Hull Data

LWL	9.88m
Breadth	3.05m
Draft (F)	1.66m
Draft (A)	1.86m
Displacement	22.4t
LCB	-13.11%
Cwp	0.630
Cm	0.750
(1+K)	1.500

Wetted Hull Area
 Wetted Appendages Area
 Wetted Transom Area

Transom Width
 Half Angle of Entrance
 Half Angle of Run

Angle at 1/4 Buttock
 Bulbous Bow
 Body Type - Fwd:

Body Type - Aft:
 Service Margin

Appendage Allowance
 Appendage Form Factor

Cb 0.437
 Cp 0.582

Service Speed
 10.0knots

Resistance and Power Prediction from AutoPower V3.0.0

Project: LARC
 Date: 11 Oct 04
 Hull Type: Displacement

Hull Data

LWL	9.88m
Breadth	3.05m
Draft (F)	1.51m
Draft (A)	1.51m
Displacement	23.2t

LCB	-11.12%
Cwp	0.770
Cm	0.880

(1+K)	1.410
Wetted Hull Area	39.3m ²
Wetted Appendages Area	0.0m ²
Wetted Transom Area	0.0m ²
Transom Width	0.0m

Half Angle of Entrance	29.9deg
Half Angle of Run	0.0deg
Angle at 1/4 Buttock	0.0deg
Bulbous Bow	NO

Body Type - Fwd:	Normal
Body Type - Aft:	Normal
Service Margin	0.00%
Appendage Allowance	0.00%
Appendage Form Factor	0.0

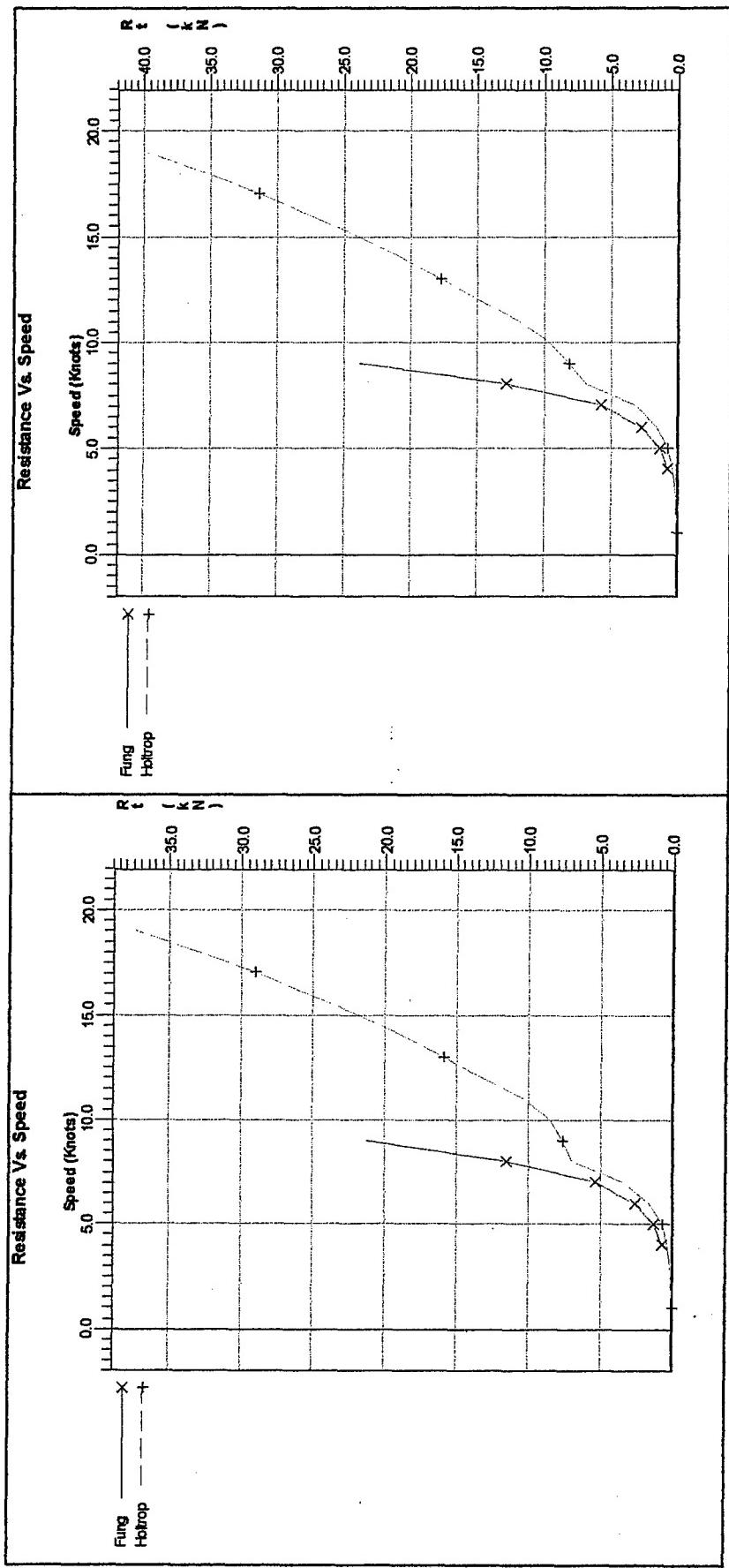
Cb 0.497
 Cp 0.565

Service Speed
 10.0knots

Speed (kt)	Fn	Fung	Holtrop
0.00	0.00	#####	0.00
1.00	0.05	#####	0.03
2.00	0.10	#####	0.11
3.00	0.16	#####	0.22
4.00	0.21	0.73	0.40
5.00	0.26	1.37	0.74
6.00	0.31	2.63	1.65
7.00	0.37	5.40	3.47
8.00	0.42	11.81	7.00
9.00	0.47	21.31	7.67
10.00	0.52	#####	8.53
11.00	0.57	#####	10.42
12.00	0.63	#####	13.19
13.00	0.68	#####	15.94
14.00	0.73	#####	18.84
15.00	0.78	#####	21.97
16.00	0.84	#####	25.39
17.00	0.89	#####	29.11
18.00	0.94	#####	33.13
19.00	0.99	#####	37.43
20.00	1.05	#####	39.94

Speed (kt)	Fn	Fung	Holtrop
0.00	0.00	#####	0.00
1.00	0.05	#####	1.00
2.00	0.10	#####	2.00
3.00	0.16	#####	3.00
4.00	0.21	0.73	4.00
5.00	0.26	1.37	5.00
6.00	0.31	2.63	6.00
7.00	0.37	5.40	7.00
8.00	0.42	11.81	8.00
9.00	0.47	21.31	9.00
10.00	0.52	#####	10.00
11.00	0.57	#####	11.00
12.00	0.63	#####	12.00
13.00	0.68	#####	13.00
14.00	0.73	#####	14.00
15.00	0.78	#####	15.00
16.00	0.84	#####	16.00
17.00	0.89	#####	17.00
18.00	0.94	#####	18.00
19.00	0.99	#####	19.00
20.00	1.05	#####	20.00

Speed (kt)	Fn	Fung	Holtrop
0.00	0.00	#####	0.00
1.00	0.05	#####	0.05
2.00	0.10	#####	0.10
3.00	0.16	#####	0.16
4.00	0.21	0.73	0.21
5.00	0.26	1.37	0.26
6.00	0.31	2.63	0.31
7.00	0.37	5.40	0.37
8.00	0.42	11.81	0.42
9.00	0.47	21.31	0.47
10.00	0.52	#####	0.52
11.00	0.57	#####	0.57
12.00	0.63	#####	0.63
13.00	0.68	#####	0.68
14.00	0.73	#####	0.73
15.00	0.78	#####	0.78
16.00	0.84	#####	0.84
17.00	0.89	#####	0.89
18.00	0.94	#####	0.94
19.00	0.99	#####	0.99
20.00	1.05	#####	1.05



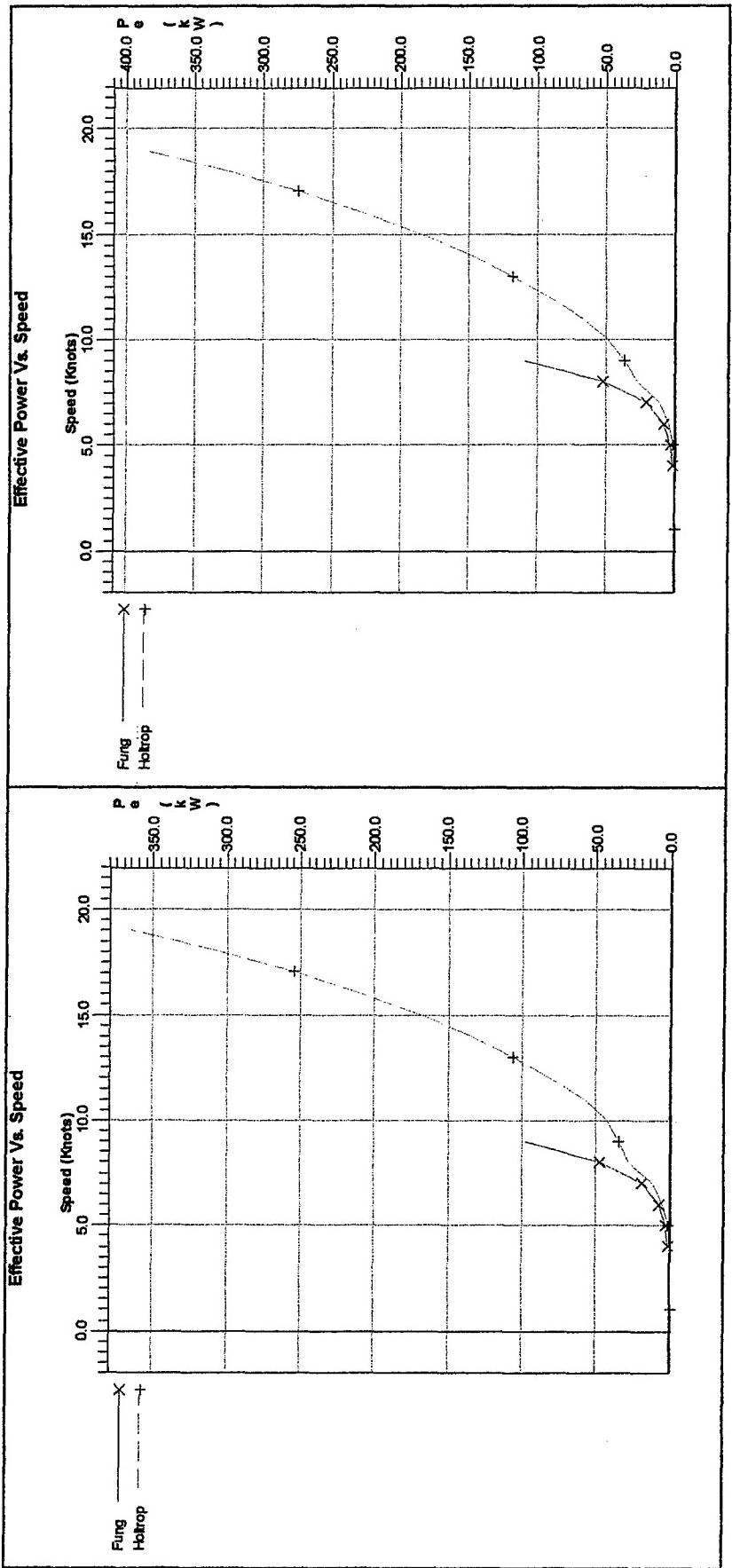
Fung and Holtrop Methods for Displacement Hull using Holtrop/Mennen wetted surface area

Effective Power, PE (kW)

Speed (kt) Fn	Fung	Holtrop
0.00	0.00 #####	0.00
1.00	0.05 #####	0.02
2.00	0.10 #####	0.11
3.00	0.16 #####	0.34
4.00	0.21 1.50	0.81
5.00	0.26 3.53	1.91
6.00	0.31 8.11	5.09
7.00	0.37 19.45	12.48
8.00	0.42 47.80	28.81
9.00	0.47 98.68	35.49
10.00	0.52 #####	43.91
11.00	0.57 #####	58.95
12.00	0.63 #####	81.40
13.00	0.68 #####	106.63
14.00	0.73 #####	135.70
15.00	0.78 #####	169.57
16.00	0.84 #####	209.00
17.00	0.89 #####	254.58
18.00	0.94 #####	306.76
19.00	0.99 #####	365.39
20.00	1.05 #####	433.00

Effective Power, PE (kW)

Speed (kt) Fn	Fung	Holtrop
0.00	0.00 #####	0.00
1.00	0.05 #####	0.05
2.00	0.10 #####	0.10
3.00	0.16 #####	0.16
4.00	0.21 1.54	0.21
5.00	0.26 3.65	0.26
6.00	0.31 8.45	0.31
7.00	0.37 21.02	0.37
8.00	0.42 53.06	0.42
9.00	0.47 110.45	0.47
10.00	0.52 #####	10.00
11.00	0.57 #####	11.00
12.00	0.63 #####	12.00
13.00	0.68 #####	13.00
14.00	0.73 #####	14.00
15.00	0.78 #####	15.00
16.00	0.84 #####	16.00
17.00	0.89 #####	17.00
18.00	0.94 #####	18.00
19.00	0.99 #####	19.00
20.00	1.05 #####	20.00



Fung and Holtrop Methods for Displacement Hull using Holtrop/Mennen wetted surface area

Radojcic/Savicki Methods for Planning Hull

Resistance and Power Prediction from AutoPower V3.0.0

Project: LARC1
Date: 11 Oct 04
Hull Type: Planing

Hull Data

LWL	9.88m	LWL	9.88m
Breadth	3.05m	Breadth	3.05m
Draft	1.66m	Draft	1.51m
Chine Beam	2.99m	Chine Beam	2.99m
Chine Length	7.90m	Chine Length	7.90m
CX	0.750	CX	0.880
Displacement	21.8t	Displacement	22.6t
LCG	3.64m	LCG	3.84m
Half Angle of Entrance	31.50deg	Half Angle of Entrance	29.90deg
Deadrise Angle	30.0deg	Deadrise Angle	30.0deg
Wetted Hull Area	99.5m ²	Wetted Hull Area	92.2m ²
Wetted Transom Area	0.0m ²	Wetted Transom Area	0.0m ²
Strut Type	Single	Strut Type	Single
Shaft Angle	0.0deg	Shaft Angle	0.0deg
Shaft Length	0.0m	Shaft Length	0.0m
Shaft Diameter	0.0m	Shaft Diameter	0.0m
Projected Skeg Area	0.0m ²	Projected Skeg Area	0.0m ²
Number of Sea Inlets	0	Number of Sea Inlets	0
Projected Area of Inlets	0.0m ²	Projected Area of Inlets	0.0m ²
Rudder Type	O-NACA 0015	Rudder Type	O-NACA 0015
Rudder Surface Area	0.0m ²	Rudder Surface Area	0.0m ²
Flap	NO	Flap	NO
Service Margin	0.00%	Service Margin	0.00%
Appendage Allowance	0.00%	Appendage Allowance	0.00%
Service Speed	19.0knots	Service Speed	19.0knots

Resistance and Power Prediction from AutoPower V3.0.0

Project: LARC1
Date: 11 Oct 04
Hull Type: Planing

Hull Data

LWL	9.88m	LWL	9.88m
Breadth	3.05m	Breadth	3.05m
Draft	1.66m	Draft	1.51m
Chine Beam	2.99m	Chine Beam	2.99m
Chine Length	7.90m	Chine Length	7.90m
CX	0.750	CX	0.880
Displacement	21.8t	Displacement	22.6t
LCG	3.64m	LCG	3.84m
Half Angle of Entrance	31.50deg	Half Angle of Entrance	29.90deg
Deadrise Angle	30.0deg	Deadrise Angle	30.0deg
Wetted Hull Area	99.5m ²	Wetted Hull Area	92.2m ²
Wetted Transom Area	0.0m ²	Wetted Transom Area	0.0m ²
Strut Type	Single	Strut Type	Single
Shaft Angle	0.0deg	Shaft Angle	0.0deg
Shaft Length	0.0m	Shaft Length	0.0m
Shaft Diameter	0.0m	Shaft Diameter	0.0m
Projected Skeg Area	0.0m ²	Projected Skeg Area	0.0m ²
Number of Sea Inlets	0	Number of Sea Inlets	0
Projected Area of Inlets	0.0m ²	Projected Area of Inlets	0.0m ²
Rudder Type	O-NACA 0015	Rudder Type	O-NACA 0015
Rudder Surface Area	0.0m ²	Rudder Surface Area	0.0m ²
Flap	NO	Flap	NO
Service Margin	0.00%	Service Margin	0.00%
Appendage Allowance	0.00%	Appendage Allowance	0.00%
Service Speed	19.0knots	Service Speed	19.0knots

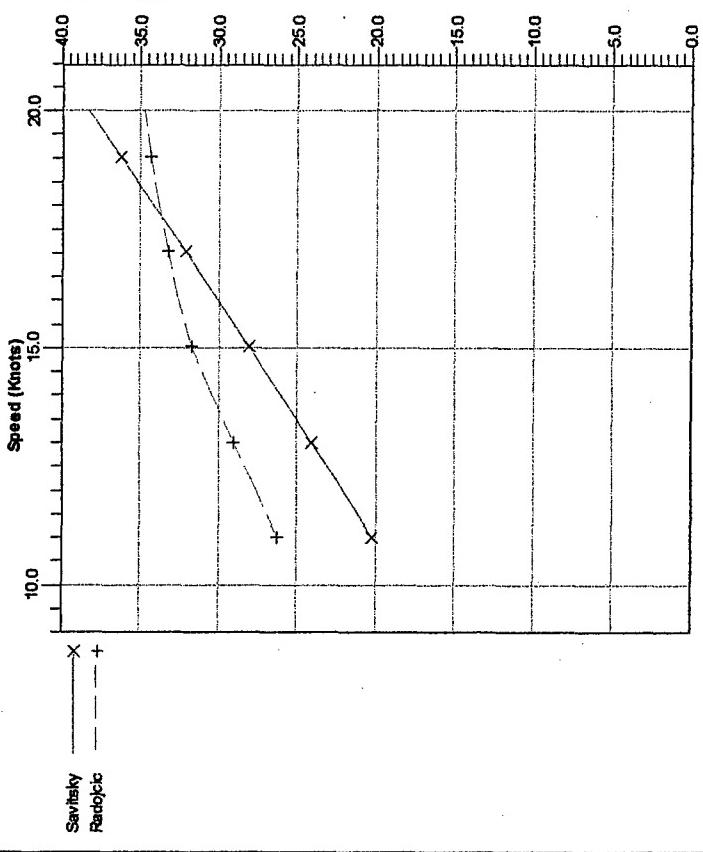
Total Resistance, R_t (kN)

Speed (kt) Fn	Savitsky	Radojcic
11.00	0.57	20.24
12.00	0.63	22.18
13.00	0.68	24.13
14.00	0.73	26.11
15.00	0.78	28.13
16.00	0.84	30.13
17.00	0.89	32.16
18.00	0.94	34.21
19.00	0.99	36.23
20.00	1.05	38.32

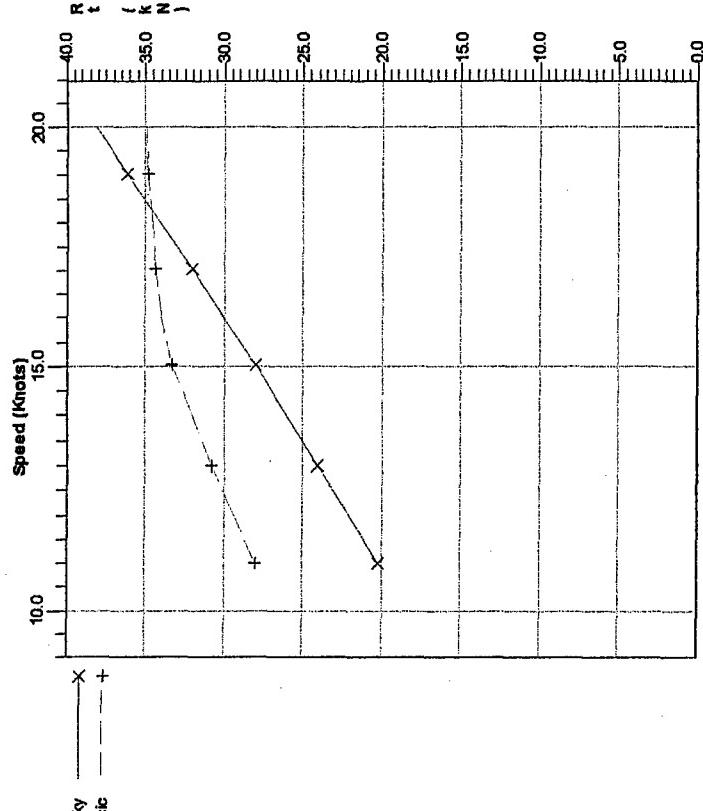
Total Resistance, R_t (kN)

Speed (kt) Fn	Savitsky	Radojcic
11.00	26.24	26.24
12.00	27.67	27.67
13.00	29.07	29.07
14.00	30.44	30.44
15.00	31.76	31.76
16.00	32.61	32.61
17.00	33.27	33.27
18.00	33.83	33.83
19.00	34.35	34.35
20.00	34.80	34.80

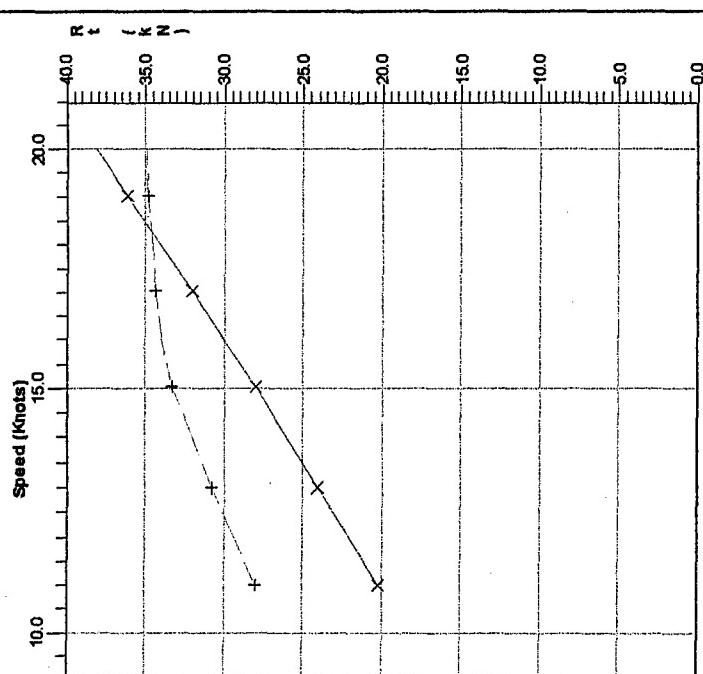
Resistance Vs. Speed



Resistance Vs. Speed



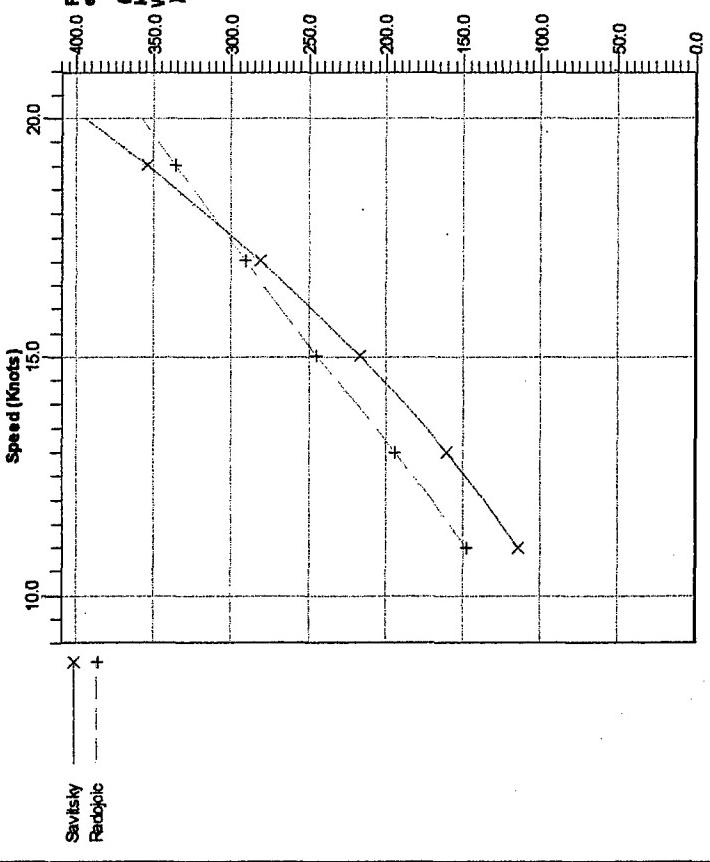
Resistance Vs. Speed



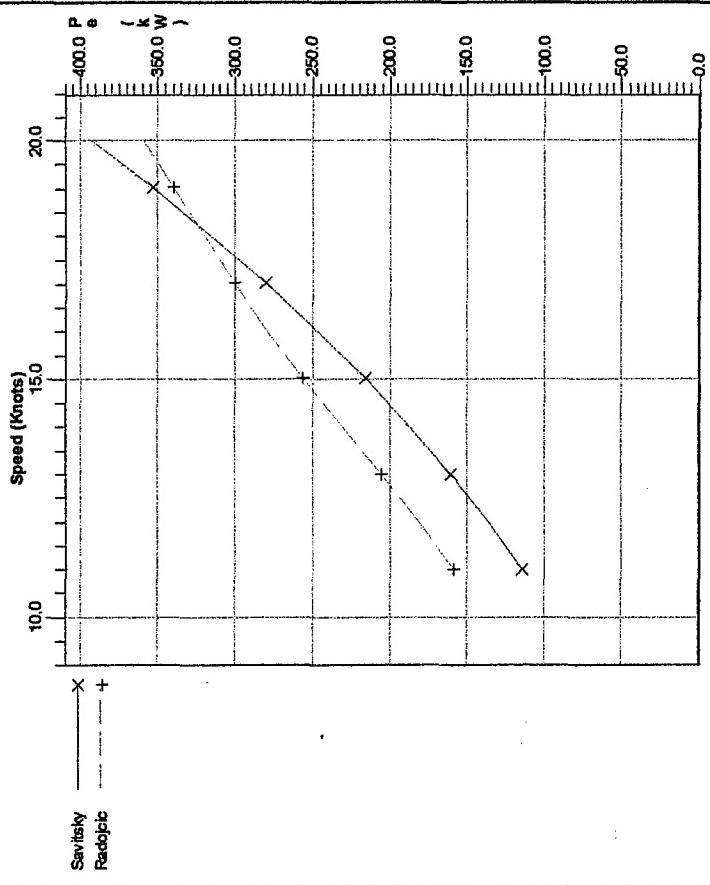
Effective Power, PE (kW)

Speed (kt) Fn	Radojcic	Savitsky
11.00	0.57	114.56
12.00	0.63	136.95
13.00	0.68	161.35
14.00	0.73	188.07
15.00	0.78	217.04
16.00	0.84	248.02
17.00	0.89	281.26
18.00	0.94	316.78
19.00	0.99	354.16
20.00	1.05	394.31

Effective Power Vs. Speed



Effective Power Vs. Speed



Effective Power Vs. Speed

Radiojic/Savicki Methods for Planning Hull With Savicki's Blount Multiplier

Resistance and Power Prediction from AutoPower V3.0.0

Project: LARC1
Date: 11 Oct 04
Hull Type: Planing

Resistance and Power Prediction from AutoPower V3.0.0

Project: LARC
Date: 11 Oct 04
Hull Type: Planing

Hull Data	Hull Data
LWL	9.88m
Breadth	3.05m
Draft	1.66m
Chine Beam	2.99m
Chine Length	7.90m
CX	0.750
Displacement	21.8t
LCG	3.64m
Half Angle of Entrance	31.50deg
Deadrise Angle	30.0deg
Wetted Hull Area	99.5m ²
Wetted Transom Area	0.0m ²
Strut Type	Single
Shaft Angle	0.0deg
Shaft Length	0.0m
Shaft Diameter	0.0m
Projected Skeg Area	0.0m ²
Number of Sea Inlets	0
Projected Area of Inlets	0.0m ²
Rudder Type	0-NACA 0015
Rudder Surface Area	0.0m ²
Flap	NO
Service Margin	0.00%
Appendage Allowance	0.00%
Service Speed	19.0knots
	19.0knots

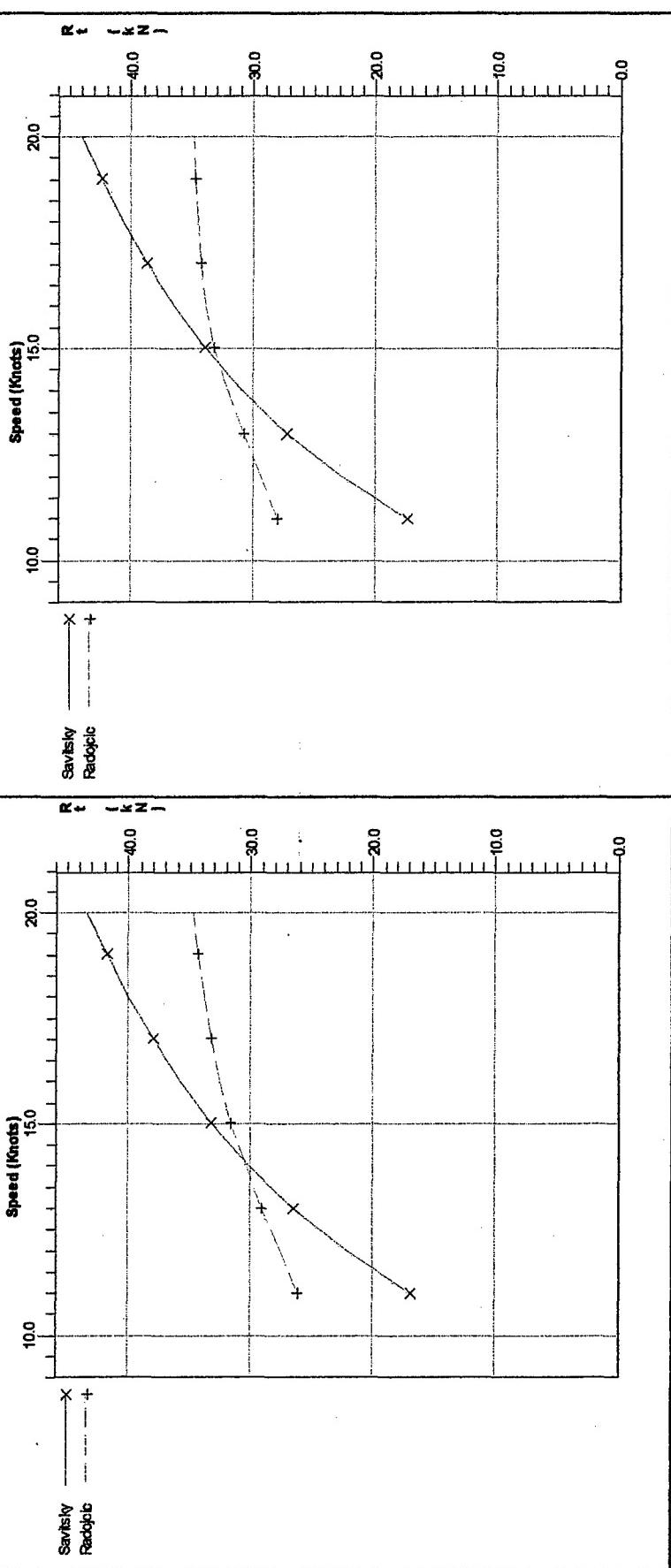
Total Resistance, R_t (kN)

Speed (kt) Fn	Savitsky	Radojcic
11.00	0.57	16.96
12.00	0.63	22.24
13.00	0.68	26.59
14.00	0.73	30.22
15.00	0.78	33.27
16.00	0.84	35.83
17.00	0.89	38.06
18.00	0.94	40.04
19.00	0.99	41.81
20.00	1.05	43.53

Total Resistance, R_t (kN)

Speed (kt) Fn	Savitsky	Radojcic
11.00	11.00	26.24
12.00	12.00	27.67
13.00	13.00	29.07
14.00	14.00	30.44
15.00	15.00	31.76
16.00	16.00	32.61
17.00	17.00	33.27
18.00	18.00	33.83
19.00	19.00	34.35
20.00	20.00	34.80

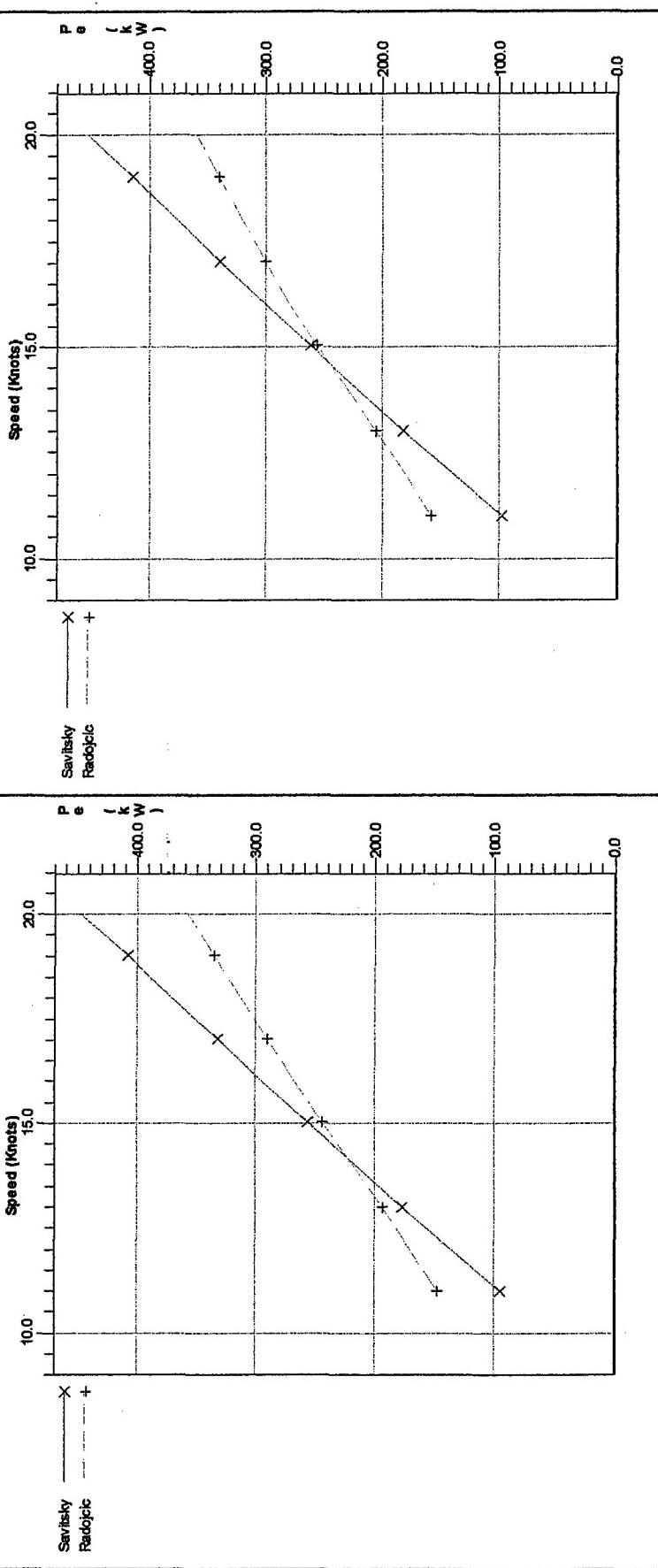
Resistance Vs Speed



Effective Power, PE (kW)

Speed (kt) Fn	Savitsky	Radojicic
11.00	0.57	95.99
12.00	0.63	137.30
13.00	0.68	177.81
14.00	0.73	217.63
15.00	0.78	256.70
16.00	0.84	294.91
17.00	0.89	332.82
18.00	0.94	370.80
19.00	0.99	408.68
20.00	1.05	447.88

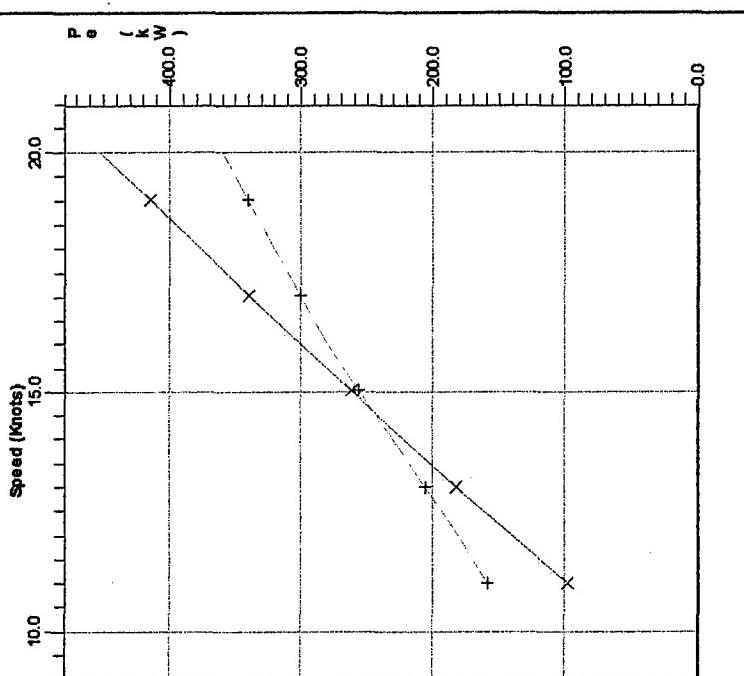
Effective Power Vs. Speed



Effective Power, PE (kW)

Speed (kt) Fn	Savitsky	Radojicic
11.00	0.57	95.99
12.00	0.63	137.30
13.00	0.68	177.81
14.00	0.73	217.63
15.00	0.78	256.70
16.00	0.84	294.91
17.00	0.89	332.82
18.00	0.94	370.80
19.00	0.99	408.68
20.00	1.05	447.88

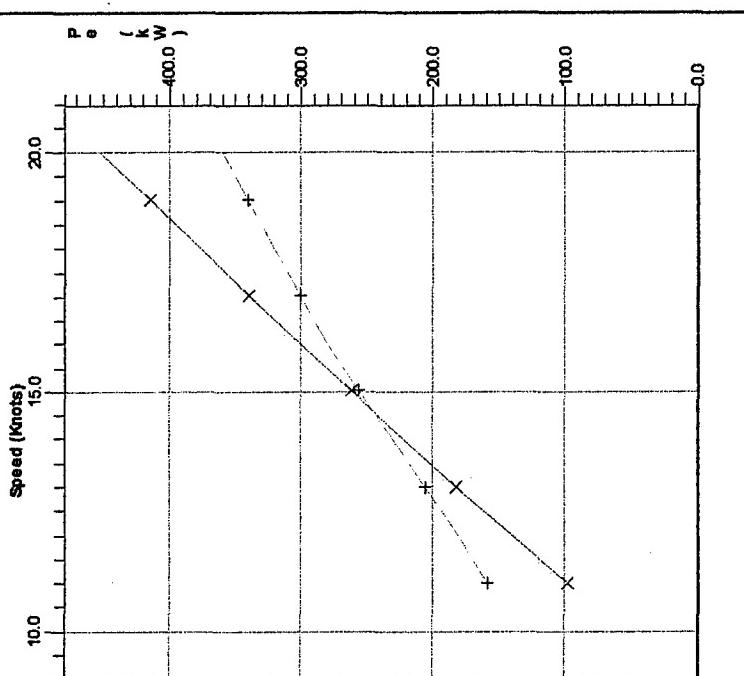
Effective Power Vs. Speed



Radojicic

Speed (kt) Fn	Savitsky	Radojicic
11.00	0.57	148.49
12.00	0.63	170.83
13.00	0.68	194.44
14.00	0.73	219.22
15.00	0.78	245.06
16.00	0.84	268.44
17.00	0.89	290.96
18.00	0.94	313.27
19.00	0.99	335.77
20.00	1.05	358.04

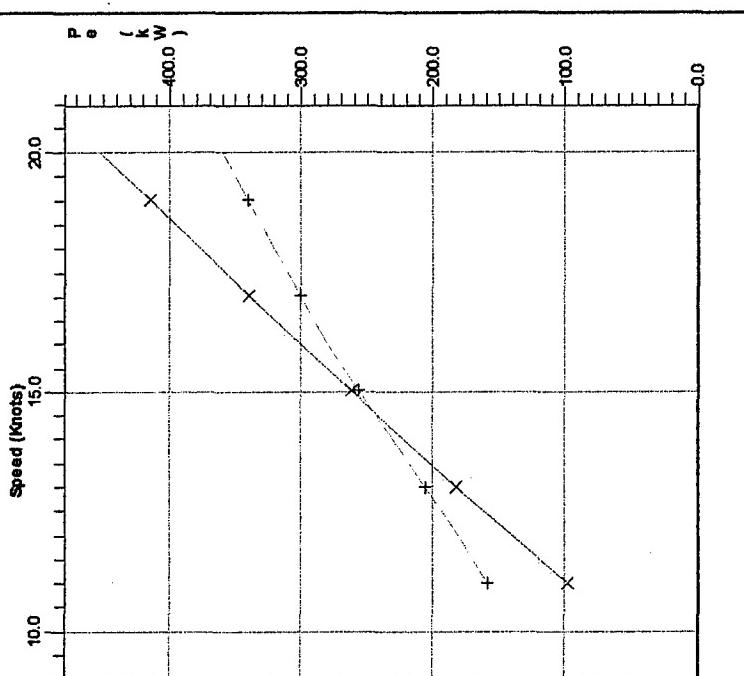
Effective Power Vs. Speed



Savitsky

Speed (kt) Fn	Savitsky	Radojicic
11.00	0.57	95.99
12.00	0.63	137.30
13.00	0.68	177.81
14.00	0.73	217.63
15.00	0.78	256.70
16.00	0.84	294.91
17.00	0.89	332.82
18.00	0.94	370.80
19.00	0.99	408.68
20.00	1.05	447.88

Effective Power Vs. Speed



Appendix 8. LARC V AUTOSHIP Model Tables of Characteristics

LARC V:

Weights and Areas, Hydrostatics, and Tables of Offsets

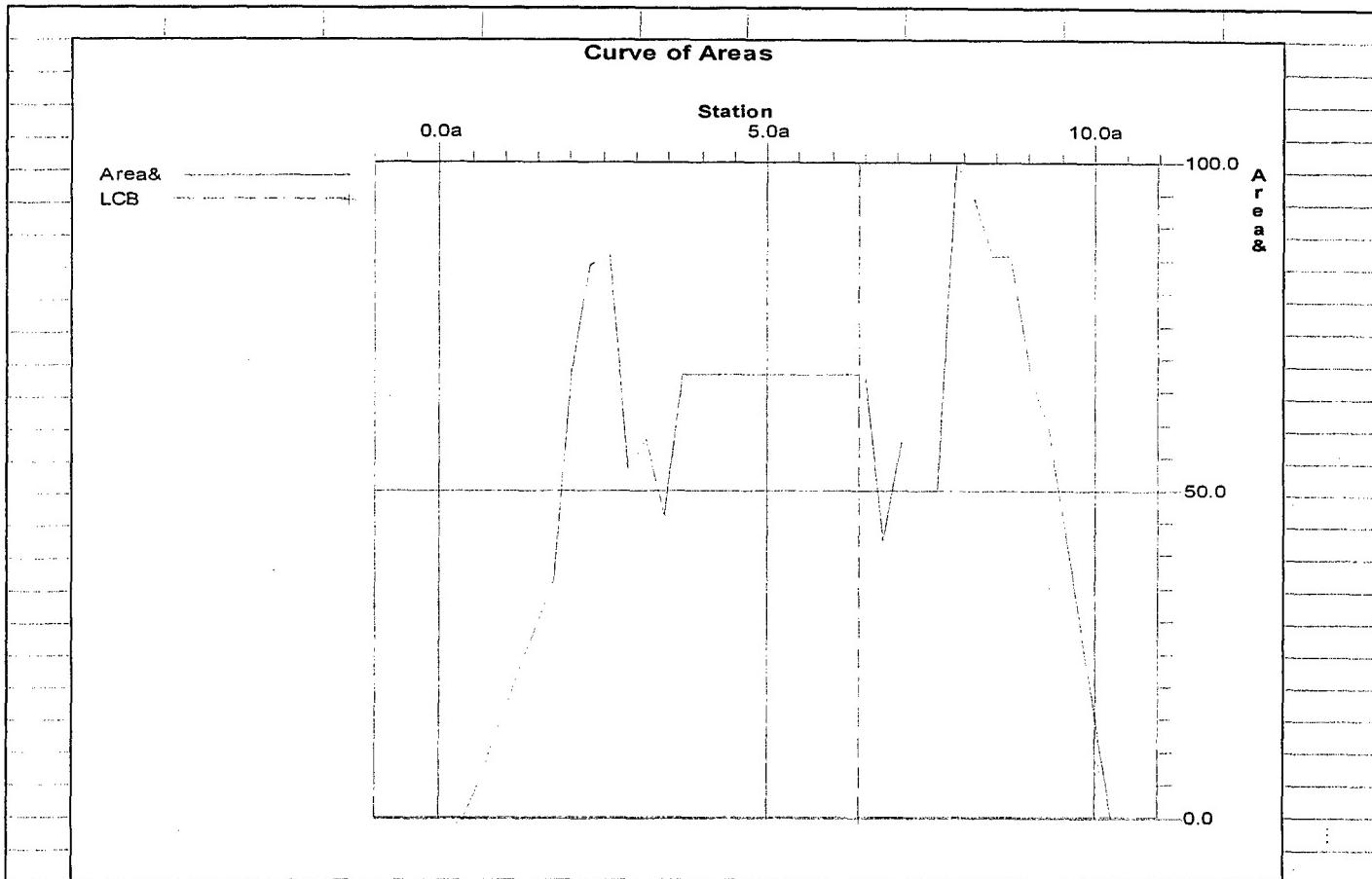
Weights and Areas

Weight Report: LARC					
Length Units: m	Weight Units: mt	Volume Units: cu.m.			
Name	Material	Spgr	Area	Volume	Weight
Group: LARC					
Bow		2.71	7.7878	0.0495	0.134
Hull*1		2.71	31.0561	0.1972	0.534
Trim of Hull Side	None	2.71	11.5834	0.0736	0.199
Trim2 of Bow Deck Plate	None	2.71	3.5567	0.0226	0.061
AFT Cube	None	100	5.0168	0.0319	3.186
AFT Wheel		3	7.4093	0.0470	0.141
FWD Wheel		3	7.4093	0.0470	0.141
Prop tube		8	1.4211	0.0108	0.087
FWD Cube	None	75	5.0168	0.0319	2.389
Bow		2.71	7.7878	0.0495	0.134
Hull*1		2.71	31.0561	0.1972	0.534
Trim of Hull Side	None	2.71	11.5834	0.0736	0.199
Trim2 of Bow Deck Plate	None	2.71	3.5567	0.0226	0.061
AFT Cube	None	100	5.0168	0.0319	3.186
AFT Wheel		3	7.4093	0.0470	0.141
FWD Wheel		3	7.4093	0.0470	0.141
Prop tube		8	1.4211	0.0108	0.087
FWD Cube	None	75	5.0168	0.0319	2.389
Totals			160.5145	1.0229	13.746
Centroid(m):	x: 5.4746	y: 0.0000	z: 0.5216		
Group					
LARC					
Surf: Bow					
Surf: Hull*1					
Poly: Trim of Hull Side					
Poly: Trim2 of Bow Deck Plate					
Poly: AFT Cube					
Surf: AFT Wheel					
Surf: FWD Wheel					
Surf: Prop tube					
Poly: FWD Cube					

Hydrostatics...

Upright Hydrostatics: LARC			
Length Units: m	Origin Depth: 0.9000		Weight Units: mt
<u>Sta.</u>	<u>Loc</u>		<u>Area Sq. m</u>
0.62	0.6168		0.2555
0.9	0.8960		0.5891
1.18	1.1752		0.8877
1.45	1.4544		1.1864
1.73	1.7336		1.4720
2.01	2.0128		2.7859
2.29	2.2920		3.4161
2.57	2.5712		3.4887
2.85	2.8504		2.1593
3.13	3.1296		2.3484
3.41	3.4088		1.8709
3.69	3.6880		2.7432
3.97	3.9672		2.7432
4.25	4.2464		2.7432
4.53	4.5256		2.7432
4.8	4.8048		2.7432
5.08	5.0840		2.7432
5.36	5.3632		2.7432
5.64	5.6424		2.7432
5.92	5.9216		2.7432
6.2	6.2008		2.7432
6.48	6.4800		2.7432
6.76	6.7592		1.7126
7.04	7.0384		2.3274
7.32	7.3176		2.2798
7.6	7.5968		2.0344
7.88	7.8760		4.0533
8.16	8.1552		3.8282
8.43	8.4344		3.4739
8.71	8.7136		3.4739
8.99	8.9928		2.7432
9.27	9.2720		2.4213
9.55	9.5512		1.7192
9.83	9.8304		1.0171
10.11	10.1096		0.3151

Hydrostatics...



Dimensions:

L.O.A.	10.6680	L.W.L.	9.8803
Immersed Length	9.8803		
Bmax.	3.0480	B.W.L.	3.0480
Immersed Volume	22.61 cu.m.		
FW Displacement	22.610 mt	SW Displacement	23.175 mt

Centroids:

LCB	6.3963 (38.9 & aft)	LCF	7.1767 (31.0 & aft)
TCB	0.0000	VCB	0.4086

Coefficients:

Block (Cb)	0.497	Prismatic (Cp)	0.565
Midships (Cm)	0.881	Waterplane (Cwp)	0.772
Volume (Cv)	23.442		

Areas:			
Water Plane	23.253 sq.m	Wetted Surface	92.200 sq.m

Ratios:			
L/B Ratio	3.500	D/L Ratio	651.937

Immersion:			
Load Increment / Draft Increment	23.253 mt/m		

Metacentre:	Transverse Radius (BMT)	1.2659 m	

Offsets

LARC			Offset Table			Measurement Units: m		
3D Curve Offsets:			3D Curve Offsets:					
x	y	z	x	y	z			
7.4465	1.5240	1.2192	2.4766	1.5240	2.1336			
7.0000	1.5240	1.2192	2.6670	1.5240	2.1336			
6.0000	1.5240	1.2192	2.6670	1.5000	2.1336			
5.0000	1.5240	1.2192	2.6670	1.0000	2.1336			
4.0000	1.5240	1.2192	2.6670	0.5000	2.1336			
3.0000	1.5240	1.2192	2.6670	0.0000	2.1336			
2.6670	1.5240	1.2192	2.0000	0.0000	2.1336			
2.6670	1.5240	1.0000	1.0000	0.0000	2.1336			
2.6670	1.5240	0.5000	0.0000	0.0000	2.1336			
2.6670	1.5240	0.0000	0.0854	0.5000	2.1336			
3.0000	1.5240	0.0000	0.3740	1.0000	2.1336			
4.0000	1.5240	0.0000	1.0000	1.4218	2.1336			
5.0000	1.5240	0.0000	1.2598	1.5000	2.1336			
6.0000	1.5240	0.0000	2.0000	1.5240	2.1336			
7.0000	1.5240	0.0000	2.3838	1.5240	2.1336			
8.0000	1.5240	0.0000	2.4043	1.5000	2.1336			
9.0000	1.5240	0.0000	2.4766	1.4152	2.1336			
9.1440	1.5240	0.0000						
9.7499	1.5240	0.5000						
10.0000	1.5240	0.7071						
10.3561	1.5240	1.0000						
10.6680	1.5240	1.2573						
10.6680	1.5240	1.5000						
10.6680	1.5240	2.0000						
10.6680	1.5240	2.1336						
10.0000	1.5240	2.1336						
9.0000	1.5240	2.1336						
8.0000	1.5240	2.1336						
7.6200	1.5240	2.1336						
7.6200	1.5240	2.0000						
7.6200	1.5240	1.5000						
7.6200	1.5240	1.2192						
7.4465	1.5240	1.2192						
Station: 1.00			x	y	z			
			1.0000		1.4309	2.1336		
			1.0000		1.3313	2.0000		
			1.0000		1.1499	1.7118		
			1.0000		1.0894	1.5000		
			1.0000		1.0000	1.0684		
			1.0000		0.9812	1.0000		
			1.0000		0.5000	0.4902		
			1.0000		0.5198	0.5000		
			1.0000		0.0000	0.3915		
Station: 2.00			x	y	z			
			2.0000		1.5240	2.1336		
			2.0000		1.5072	2.0000		
			2.0000		1.5000	1.9486		
			2.0000		1.4409	1.5000		

Offsets

		2.0000		1.4143	1.0000
		2.0000		1.3207	0.5509
		2.0000		1.2821	0.5000
		2.0000		1.0000	0.2876
		2.0000		0.5000	0.1615
		2.0000		0.0247	0.1328
Station: 3.00	x		Y	Z	
		3.0000		1.5240	0.0000
		3.0000		1.5240	0.5000
		3.0000		1.5240	1.0000
		3.0000		1.5240	1.2192
		3.0000		0.0000	0.0000
		3.0000		1.2954	1.0480
		3.0000		1.0668	1.0480
		3.0000		1.0666	1.0000
		3.0000		1.0650	0.5000
		3.0000		1.0650	0.0000
Station: 4.00	x		Y	Z	
		4.0000		0.0000	0.0000
		4.0000		0.5000	0.0000
		4.0000		1.0000	0.0000
		4.0000		1.5000	0.0000
		4.0000		1.5240	0.0000
		4.0000		1.5240	0.5000
		4.0000		1.5240	1.0000
		4.0000		1.5240	1.2192
Station: 5.00	x		Y	Z	
		5.0000		0.0000	0.0000
		5.0000		0.5000	0.0000
		5.0000		1.0000	0.0000
		5.0000		1.5000	0.0000
		5.0000		1.5240	0.0000
		5.0000		1.5240	0.5000
		5.0000		1.5240	1.0000
		5.0000		1.5240	1.2192
Station: 6.00	x		Y	Z	
		6.0000		0.0000	0.0000
		6.0000		0.5000	0.0000
		6.0000		1.0000	0.0000
		6.0000		1.5000	0.0000
		6.0000		1.5240	0.0000
		6.0000		1.5240	0.5000
		6.0000		1.5240	1.0000
		6.0000		1.5240	1.2192
Station: 7.00	x		Y	Z	
		7.0000		0.0000	0.0000
		7.0000		0.5000	0.0000
		7.0000		1.0000	0.0000
		7.0000		1.5000	0.0000
		7.0000		1.5240	0.0000
		7.0000		1.5240	1.0000
		7.0000		1.5240	1.2192

Offsets

		7.0000	1.2954	-0.4069
		7.0000	1.5240	0.9149
		7.0000	1.5240	-0.4069
		7.0000	1.5000	-0.4069
Station: 8.00	x		Y	Z
		8.0000	0.0000	0.0000
		8.0000	0.5000	0.0000
		8.0000	1.0000	0.0000
		8.0000	1.5000	0.0000
		8.0000	1.5240	1.0000
		8.0000	1.5240	1.5000
		8.0000	1.5240	2.0000
		8.0000	1.5240	2.1336
		8.0000	1.2954	0.9794
		8.0000	1.5000	-0.4714
		8.0000	1.5240	-0.4714
		8.0000	1.5226	0.0000
		8.0000	1.5226	0.5000
		8.0000	1.5240	0.9794
		8.0000	1.5000	0.9794
Station: 9.00	x		Y	Z
		9.0000	0.0000	0.0000
		9.0000	0.5000	0.0000
		9.0000	1.0000	0.0000
		9.0000	1.5000	0.0000
		9.0000	1.5240	0.0000
		9.0000	1.5240	0.5000
		9.0000	1.5240	1.0000
		9.0000	1.5240	1.5000
		9.0000	1.5240	2.0000
		9.0000	1.5240	2.1336
Station: 10.00	x		Y	Z
		10.0000	1.5240	0.7071
		10.0000	1.5240	1.0000
		10.0000	1.5240	1.5000
		10.0000	1.5240	2.0000
		10.0000	1.5240	2.1336
		10.0000	0.0000	0.7062
		10.0000	0.5000	0.7062
		10.0000	1.0000	0.7062
		10.0000	1.5000	0.7062
Station: 10.67	x		Y	Z
		10.6680	1.5240	1.2573
		10.6680	1.5240	1.5000
		10.6680	1.5240	2.0000
		10.6680	1.5240	2.1336

Appendix 9. LARC (1) Autoship Model Tables of Characteristics

Modified LARC (1):

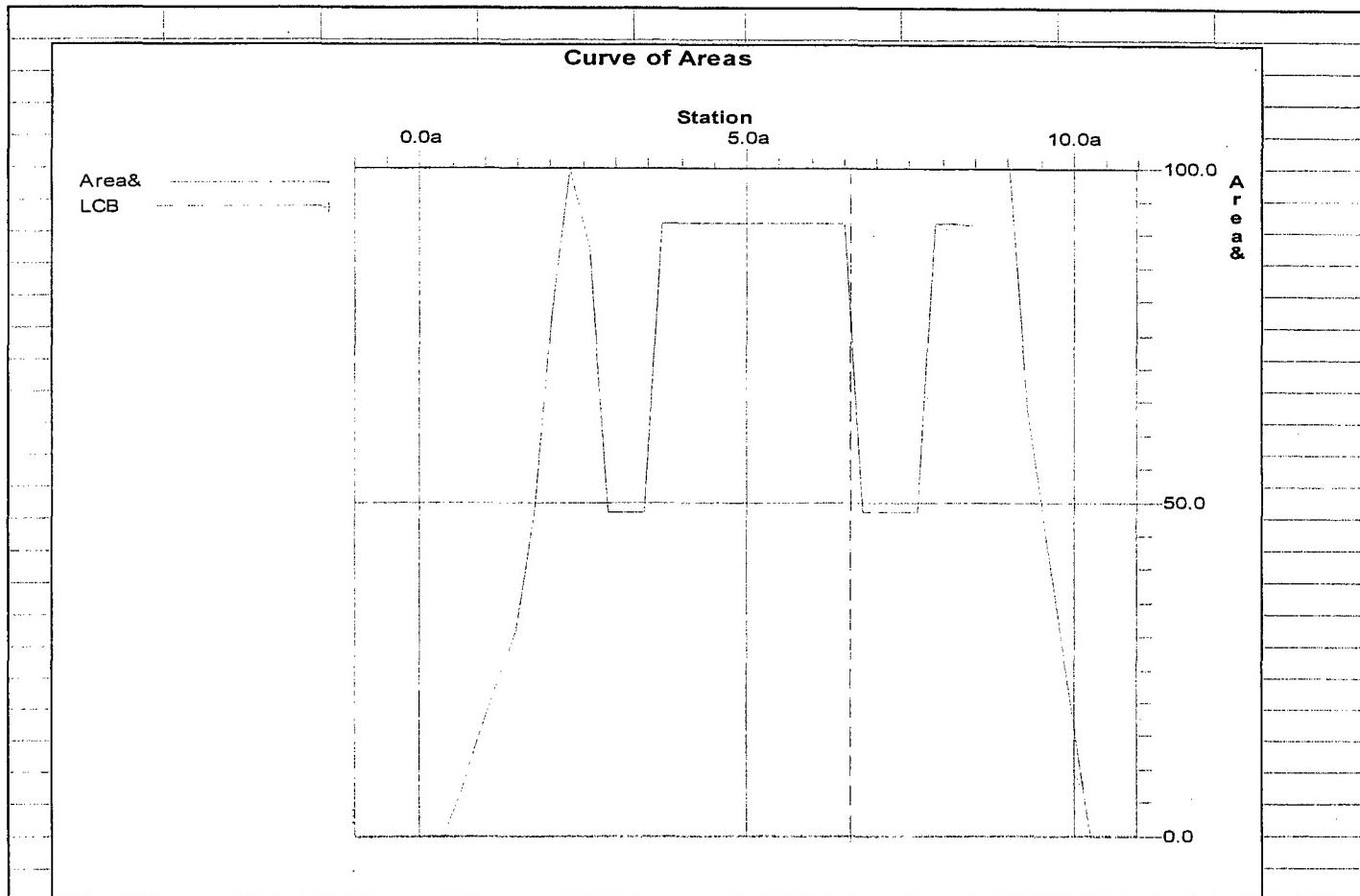
Weights and Areas, Hydrostatics, and Tables of Offsets

Weights and Areas

Hydrostatics...

Upright Hydrostatics: LARC1			
Length Units: m		Origin Depth: 0.9000	Weight Units: mt
Sta.	Loc		Area Sq. m
0.62		0.6168	0.2555
0.9		0.8960	0.5891
1.18		1.1752	0.8877
1.45		1.4544	1.1864
1.73		1.7336	1.8164
2.01		2.0128	2.9823
2.29		2.2920	3.8068
2.57		2.5712	3.3513
2.85		2.8504	1.8552
3.13		3.1296	1.8552
3.41		3.4088	1.8552
3.69		3.6880	3.5011
3.97		3.9672	3.5011
4.25		4.2464	3.5011
4.53		4.5256	3.5011
4.8		4.8048	3.5011
5.08		5.0840	3.5011
5.36		5.3632	3.5011
5.64		5.6424	3.5011
5.92		5.9216	3.5011
6.2		6.2008	3.5011
6.48		6.4800	3.5011
6.76		6.7592	1.8552
7.04		7.0384	1.8552
7.32		7.3176	1.8552
7.6		7.5968	1.8552
7.88		7.8760	3.5011
8.16		8.1552	3.5011
8.43		8.4344	3.4875
8.71		8.7136	3.6641
8.99		8.9928	3.8103
9.27		9.2720	2.4213
9.55		9.5512	1.7191
9.83		9.8304	1.0171
10.11		10.1096	0.3151

Hydrostatics...



Dimensions:

L.O.A.	10.6680	L.W.L.	9.8803
Immersed Length	9.8803		
Bmax.	3.0480	B.W.L.	3.0480
Immersed Volume	21.83 cu.m.		
FW Displacement	21.833 mt	SW Displacement	22.378 mt

Centroids:

LCB	6.5930 (36.9 & aft)	LCF	7.9527 (23.1 & aft)
TCB	0.0000	VCB	0.3053

Coefficients:

Block (Cb)	0.436	Prismatic (Cp)	0.580
Midships (Cm)	0.752	Waterplane (Cwp)	0.635
Volume (Cv)	22.636		

Areas:

Water Plane	19.109 sq.m	Wetted Surface	99.462 sq.m
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Ratios:

L/B Ratio	3.500	D/L Ratio	629.525
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Immersion:

Load Increment / Draft Increment	19.109 mt/m		
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Metacentre:	Transverse Radius (BMt)	1.0625 m	
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Offsets

LARC1			Offset Table			Measurement Units: m		
3D Curve Offsets:			3D Curve Offsets:					
X	Y	Z	X	Y	Z			
7.4465	1.5240	1.2192	2.4766	1.5240	2.1336			
7.0000	1.5240	1.2192	2.6670	1.5240	2.1336			
6.0000	1.5240	1.2192	2.6670	1.5000	2.1336			
5.0000	1.5240	1.2192	2.6670	1.5240	2.1336			
4.0000	1.5240	1.2192	2.6670	1.0000	2.1336			
3.0000	1.5240	1.2192	2.6670	0.5000	2.1336			
2.6670	1.5240	1.2192	2.6670	0.0000	2.1336			
2.6670	1.5240	1.0000	2.6670	0.0000	2.1336			
2.6670	1.5240	0.5000	2.0000	0.0000	2.1336			
2.6670	1.5240	0.0000	1.0000	0.0000	2.1336			
2.6670	1.5240	0.0000	0.0000	0.0000	2.1336			
3.0000	1.5240	0.0000	0.0000	0.0000	2.1336			
4.0000	1.5240	0.0000	0.0854	0.5000	2.1336			
5.0000	1.5240	0.0000	0.3740	1.0000	2.1336			
6.0000	1.5240	0.0000	1.0000	1.4218	2.1336			
7.0000	1.5240	0.0000	1.2598	1.5000	2.1336			
8.0000	1.5240	0.0000	2.0000	1.5240	2.1336			
9.0000	1.5240	0.0000	2.3838	1.5240	2.1336			
9.1440	1.5240	0.0000	2.4043	1.5000	2.1336			
9.1440	1.5240	0.0000	2.3838	1.5240	2.1336			
9.7499	1.5240	0.5000	2.4766	1.4152	2.1336			
10.0000	1.5240	0.7071						
10.3561	1.5240	1.0000						
10.6680	1.5240	1.2573						
10.6680	1.5240	1.2573						
10.6680	1.5240	1.5000						
10.6680	1.5240	2.0000						
10.6680	1.5240	2.1336						
10.6680	1.5240	2.1336						
10.0000	1.5240	2.1336						
9.0000	1.5240	2.1336						
8.0000	1.5240	2.1336						
7.6200	1.5240	2.1336						
7.6200	1.5240	2.1336						
7.6200	1.5240	2.0000						
7.6200	1.5240	1.5000						
7.6200	1.5240	1.2192						
7.4465	1.5240	1.2192						
Station: 1.00		X		Y	Z			
			1.0000	1.4298	2.1336			
			1.0000	1.3413	2.0000			
			1.0000	1.4298	2.1336			
			1.0000	1.1499	1.7118			
			1.0000	1.0962	1.5000			
			1.0000	1.0000	1.0684			
			1.0000	0.9812	1.0000			
			1.0000	0.5000	0.4902			
			1.0000	0.5198	0.5000			
			1.0000	0.0000	0.3921			

Offsets

Station:	X	Y	Z
Station: 2.00	2.0000	1.5240	2.1336
	2.0000	1.5072	2.0000
	2.0000	1.5000	1.9494
	2.0000	1.4408	1.5000
	2.0000	1.4143	1.0000
	2.0000	1.3207	0.5509
	2.0000	1.2821	0.5000
	2.0000	1.0000	0.2876
	2.0000	0.5000	0.1618
	2.0000	0.0247	0.1328
Station: 3.00	x	y	z
	3.0000	0.0000	0.0000
	3.0000	0.5000	0.0000
	3.0000	1.0000	0.0000
	3.0000	1.5000	0.0000
	3.0000	1.5240	0.0000
	3.0000	1.5240	0.5000
	3.0000	1.5240	1.0000
	3.0000	1.5240	1.2192
Station: 3.00	x	y	z
	3.0000	1.2452	-0.7144
	3.0000	1.5000	-0.6417
	3.0000	1.5240	-0.6350
	3.0000	1.5239	-0.6000
	3.0000	1.5235	-0.5000
	3.0000	1.5215	0.0000
	3.0000	1.0000	-0.4111
	3.0000	1.0240	-0.5000
	3.0000	1.0510	-0.6000
	3.0000	1.0947	-0.7620
	3.0000	1.2452	-0.7144
Station: 4.00	x	y	z
	4.0000	0.0000	0.0000
	4.0000	0.5000	0.0000
	4.0000	1.0000	0.0000
	4.0000	1.5000	0.0000
	4.0000	1.5240	0.0000
	4.0000	1.5240	0.5000
	4.0000	1.5240	1.0000
	4.0000	1.5240	1.2192
Station: 4.00	x	y	z
	4.0000	1.2452	-0.7144
	4.0000	1.5000	-0.6417
	4.0000	1.5240	-0.6350
	4.0000	1.5239	-0.6000
	4.0000	1.5235	-0.5000

Offsets

		4.0000	1.5215	0.0000
		4.0000	0.8890	0.0000
		4.0000	1.0000	-0.4111
		4.0000	1.0240	-0.5000
		4.0000	1.0510	-0.6000
		4.0000	1.0947	-0.7620
		4.0000	1.2452	-0.7144
Station: 5.00	x		Y	Z
		5.0000	0.0000	0.0000
		5.0000	0.5000	0.0000
		5.0000	1.0000	0.0000
		5.0000	1.5000	0.0000
		5.0000	1.5240	0.0000
		5.0000	1.5240	0.5000
		5.0000	1.5240	1.0000
		5.0000	1.5240	1.2192
Station: 5.00	x		Y	Z
		5.0000	1.2452	-0.7144
		5.0000	1.5000	-0.6417
		5.0000	1.5240	-0.6350
		5.0000	1.5240	-0.6350
		5.0000	1.5240	-0.6350
		5.0000	1.5239	-0.6000
		5.0000	1.5235	-0.5000
		5.0000	1.5215	0.0000
		5.0000	0.8890	0.0000
		5.0000	1.0000	-0.4111
		5.0000	1.0240	-0.5000
		5.0000	1.0510	-0.6000
		5.0000	1.0947	-0.7620
		5.0000	1.2452	-0.7144
Station: 6.00	x		Y	Z
		6.0000	0.0000	0.0000
		6.0000	0.5000	0.0000
		6.0000	1.0000	0.0000
		6.0000	1.5000	0.0000
		6.0000	1.5240	0.0000
		6.0000	1.5240	0.5000
		6.0000	1.5240	1.0000
		6.0000	1.5240	1.2192
Station: 6.00	x		Y	Z
		6.0000	1.2452	-0.7144
		6.0000	1.5000	-0.6417
		6.0000	1.5240	-0.6350
		6.0000	1.5239	-0.6000
		6.0000	1.5235	-0.5000
		6.0000	1.5215	0.0000
		6.0000	0.8890	0.0000

Offsets

		6.0000	1.0000	-0.4111	
		6.0000	1.0240	-0.5000	
		6.0000	1.0510	-0.6000	
		6.0000	1.0947	-0.7620	
		6.0000	1.2452	-0.7144	
Station: 7.00	x		Y	Z	
		7.0000	0.0000	0.0000	
		7.0000	0.5000	0.0000	
		7.0000	1.0000	0.0000	
		7.0000	1.5000	0.0000	
		7.0000	1.5240	0.0000	
		7.0000	1.5240	0.5000	
		7.0000	1.5240	1.0000	
		7.0000	1.5240	1.2192	
Station: 7.00	x		Y	Z	
		7.0000	1.2452	-0.7144	
		7.0000	1.5000	-0.6417	
		7.0000	1.5240	-0.6350	
		7.0000	1.5239	-0.6000	
		7.0000	1.5235	-0.5000	
		7.0000	1.5215	0.0000	
		7.0000	0.8890	0.0000	
		7.0000	1.0000	-0.4111	
		7.0000	1.0240	-0.5000	
		7.0000	1.0510	-0.6000	
		7.0000	1.0947	-0.7620	
		7.0000	1.2452	-0.7144	
Station: 8.00	x		Y	Z	
		8.0000	0.0000	0.0000	
		8.0000	0.5000	0.0000	
		8.0000	1.0000	0.0000	
		8.0000	1.5000	0.0000	
		8.0000	1.5240	0.0000	
		8.0000	1.5240	0.5000	
		8.0000	1.5240	1.0000	
		8.0000	1.5240	1.5000	
		8.0000	1.5240	2.0000	
		8.0000	1.5240	2.1336	
Station: 8.00	x		Y	Z	
		8.0000	1.2452	-0.7144	
		8.0000	1.5000	-0.6417	
		8.0000	1.5240	-0.6350	
		8.0000	1.5239	-0.6000	
		8.0000	1.5235	-0.5000	
		8.0000	1.5215	0.0000	
		8.0000	0.8890	0.0000	
		8.0000	1.0000	-0.4111	
		8.0000	1.0240	-0.5000	

Offsets

		8.0000	1.0510	-0.6000	
		8.0000	1.0947	-0.7620	
		8.0000	1.2452	-0.7144	
Station: 9.00	x		y	z	
		9.0000	0.0000	0.0000	
		9.0000	0.5000	0.0000	
		9.0000	1.0000	0.0000	
		9.0000	1.5000	0.0000	
		9.0000	1.5240	0.0000	
		9.0000	1.5240	0.5000	
		9.0000	1.5240	1.0000	
		9.0000	1.5240	1.5000	
		9.0000	1.5240	2.0000	
		9.0000	1.5240	2.1336	
Station: 9.00	x		y	z	
		9.0000	1.5220	-0.1225	
		9.0000	1.5215	0.0000	
		9.0000	0.8890	0.0000	
		9.0000	0.9223	-0.1234	
Station: 10.00	x		y	z	
		10.0000	0.0000	0.7062	
		10.0000	0.5000	0.7062	
		10.0000	1.0000	0.7062	
		10.0000	1.5000	0.7062	
		10.0000	1.5240	0.7071	
		10.0000	1.5240	1.0000	
		10.0000	1.5240	1.5000	
		10.0000	1.5240	2.0000	
		10.0000	1.5240	2.1336	
Station: 10.67	x		y	z	
		10.6680	1.5240	1.2573	
		10.6680	1.5240	1.5000	
		10.6680	1.5240	2.0000	
		10.6680	1.5240	2.1336	

Appendix 10. LARC V Characteristics

LARC V:

Characteristics, General Arrangements, Systems and Components, Propeller, Rudder, and Drive Train

APPENDIX 10

LARC V CHARACTERISTICS

The LARC V is a lightweight, aluminum hulled, terratired amphibious vehicle having moderate water speed and good surfing ability. This vehicle is not suitable for swampy terrain and is not mobile in heavily irrigated terrain. It is suitable for transporting cargo from ship to shore, to beaches, or up fairly wide rivers and canals to semiprepared landing areas.

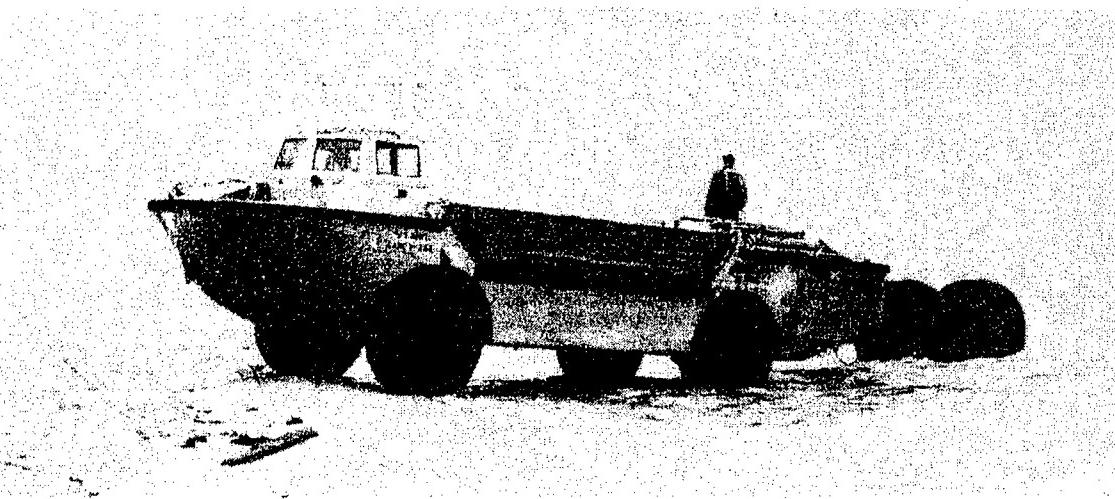
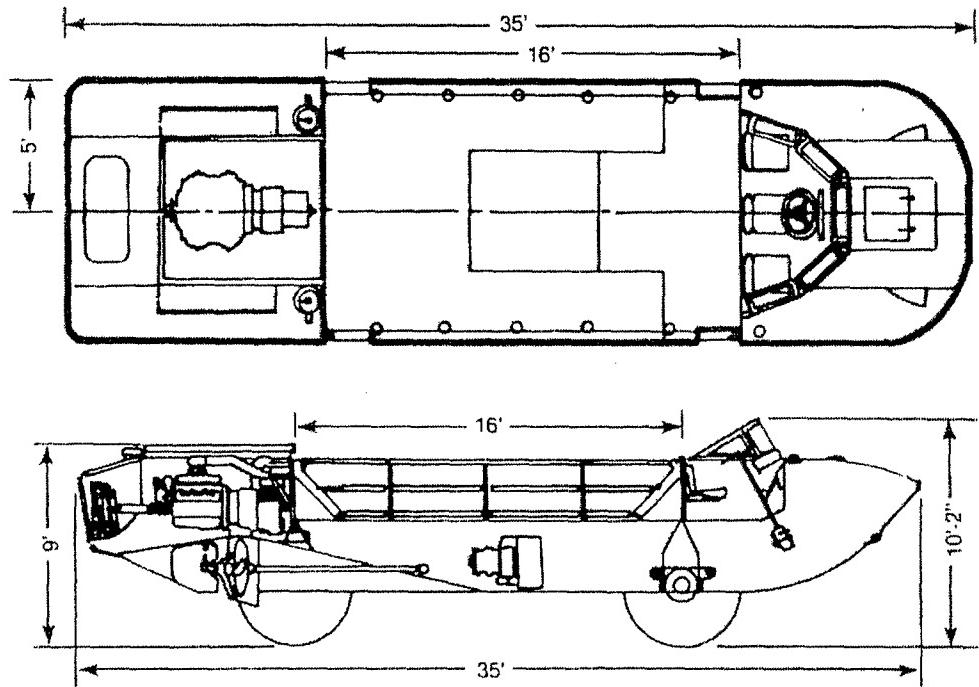
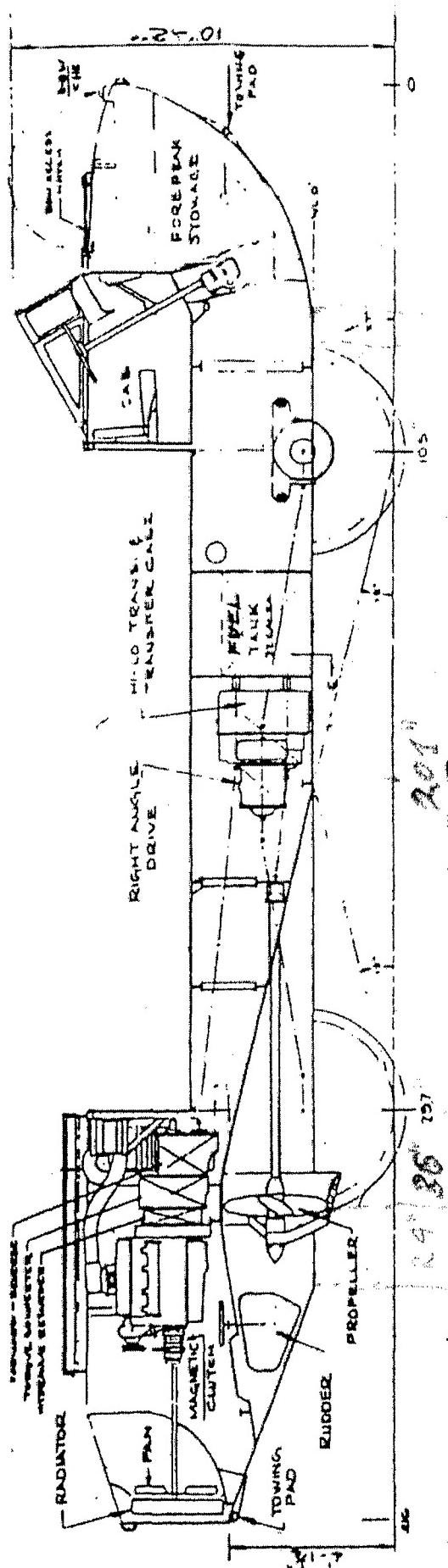
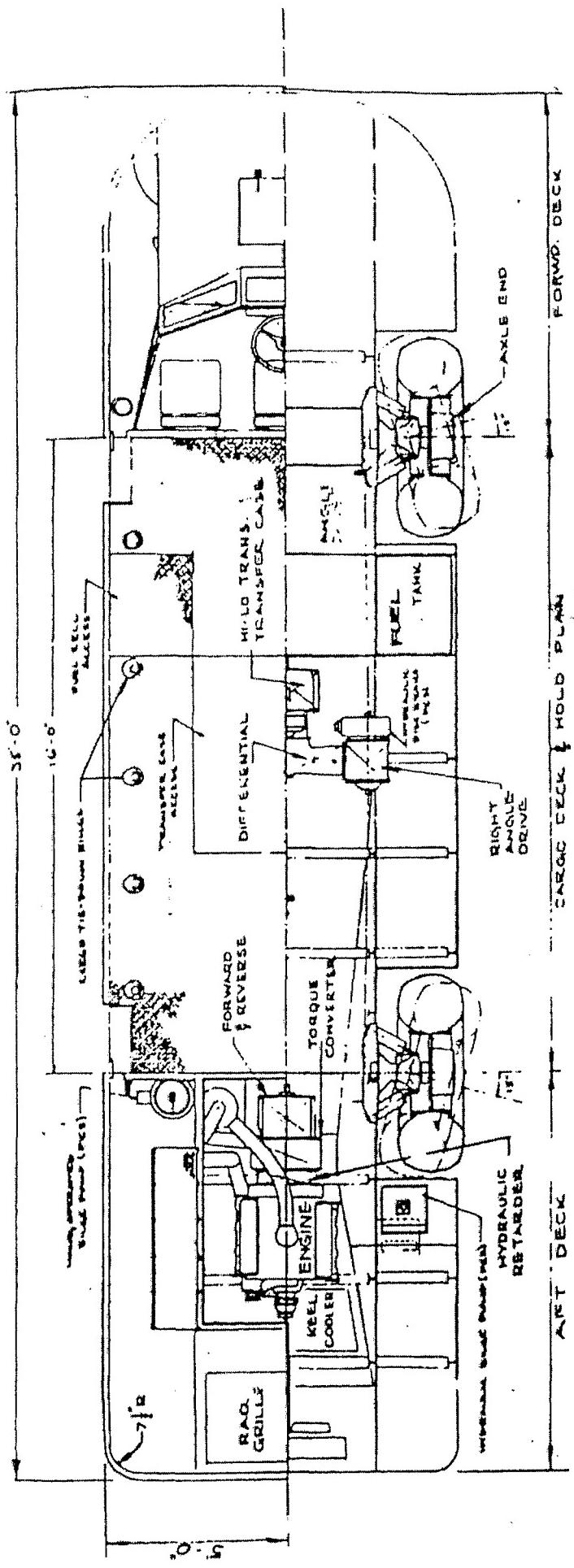


Figure G-1. Lighter, Amphibious, Resupply, Cargo, 5 Ton (LARC V).

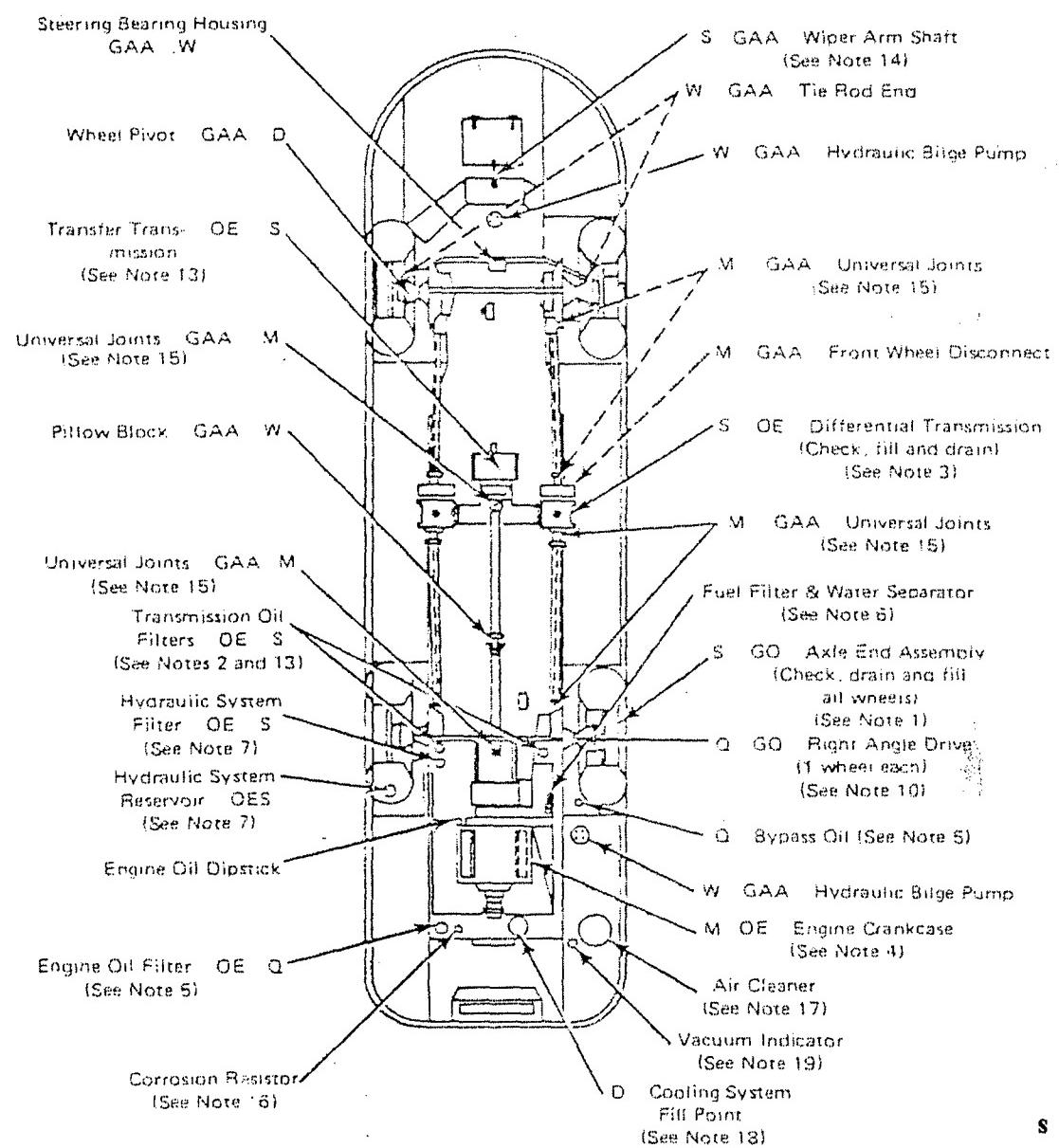
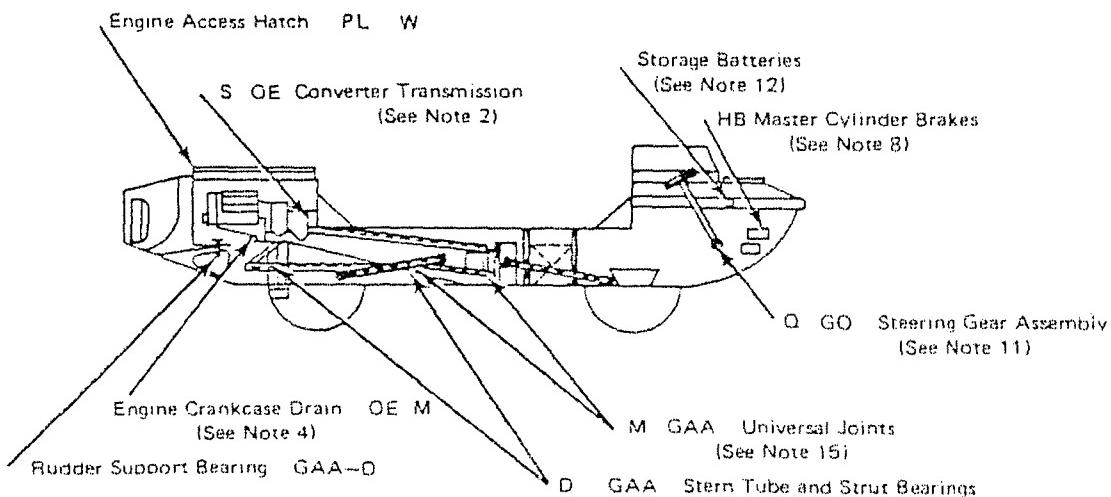
(a) Length, overall	35 feet
(b) Width, overall	10 feet
(c) Speed, loaded:	
Land	30 miles per hour
Water	8.7 knots per hour
(d) Operating range, loaded:	
Land	200 miles
Water	60 miles



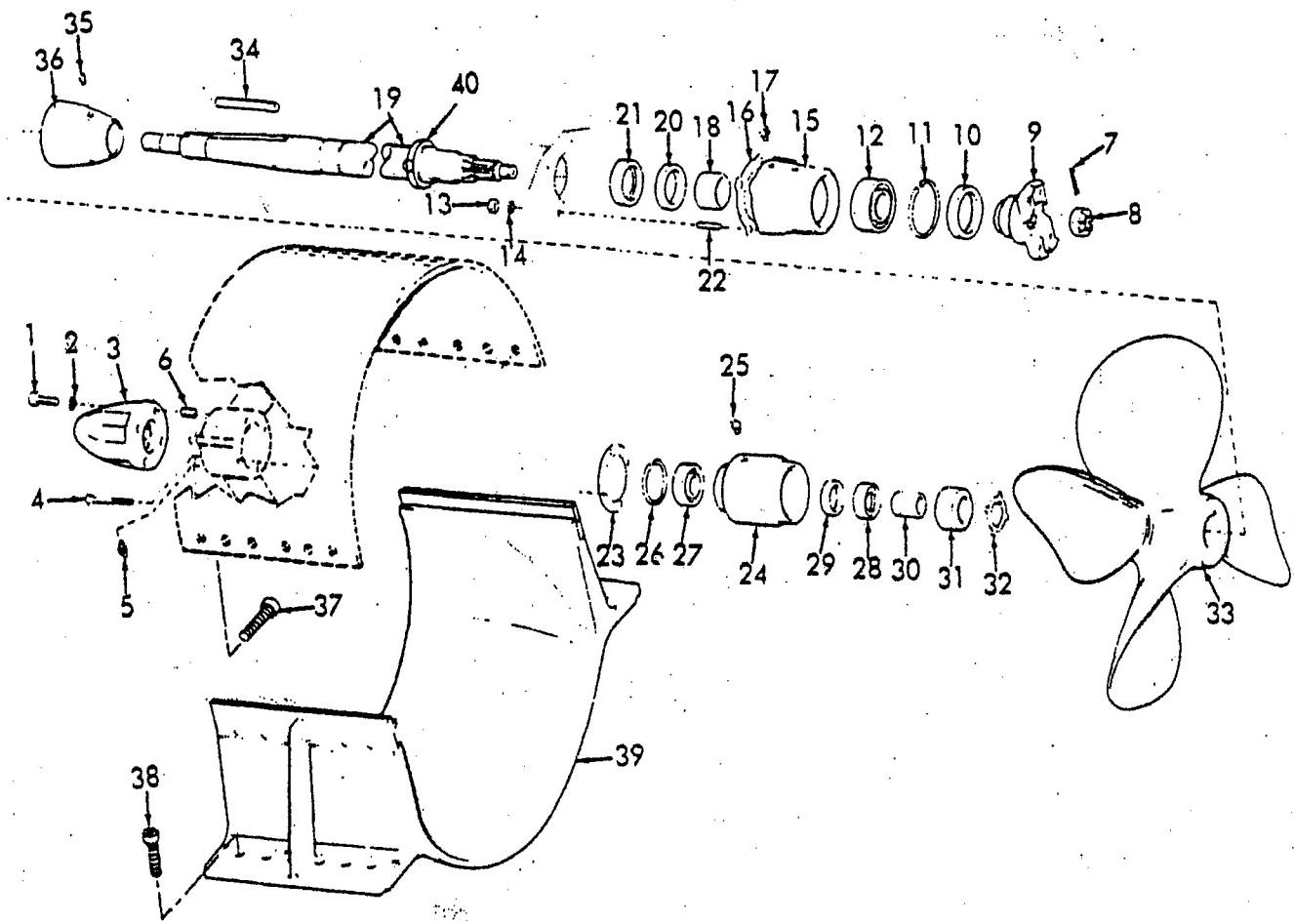
(e) Fuel consumption (gallons per hour)	20
(f) Crew	2
(g) Passenger capacities:	
Normal	0
Emergency	20
(h) Cargo capacities:	
Normal	4.5 light tons
Maximum	5 light tons

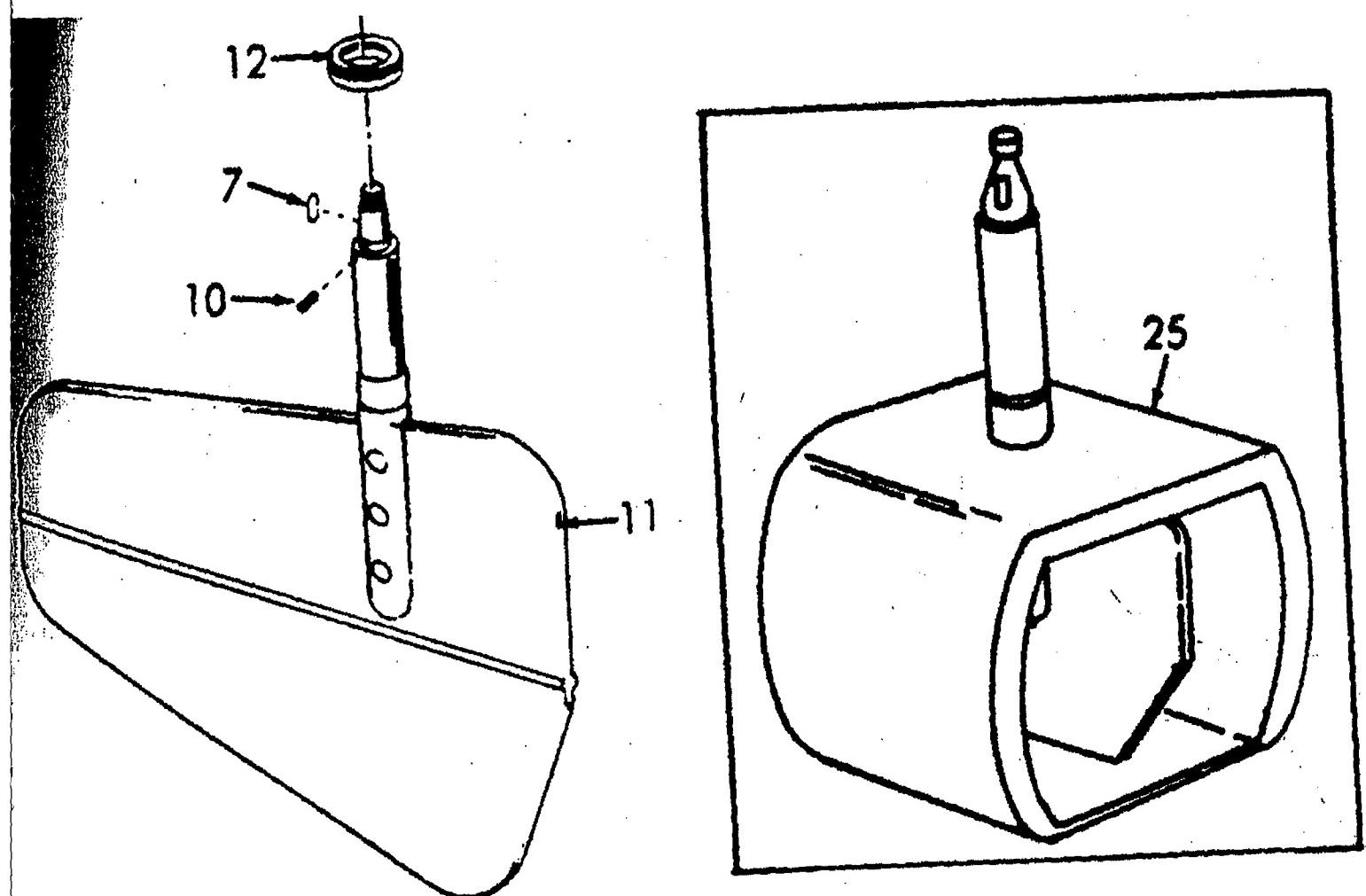


LARC General Arrangements.bmp



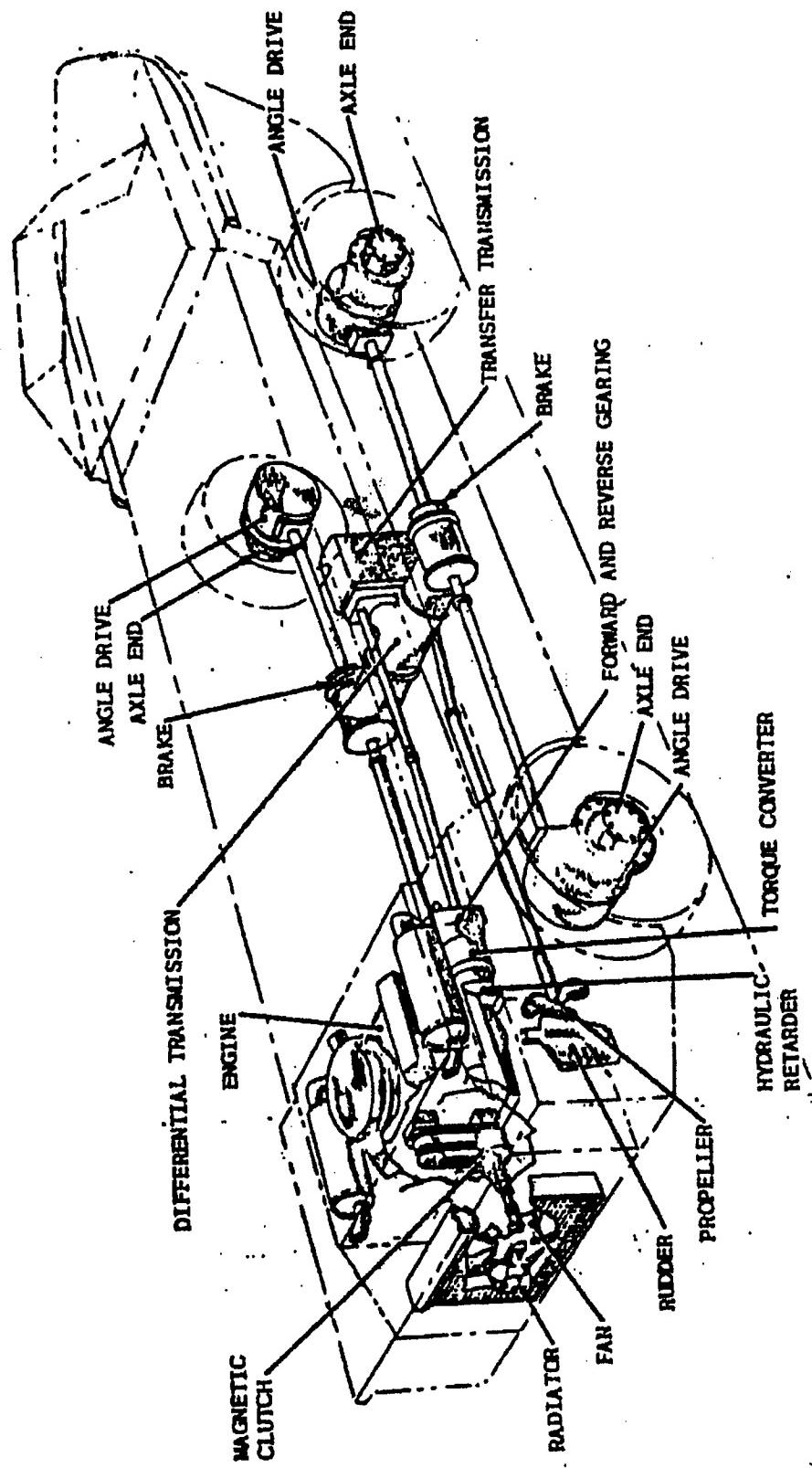
NOTE: AFTER NUT (8) IS COMPLETELY
SCREWED ONTO SHAFT, TIGHTEN
SLINGER SCREWS.





LARC Ruder.bmp

POWER TRAIN



Appendix 11. DPCAT Model Characteristics

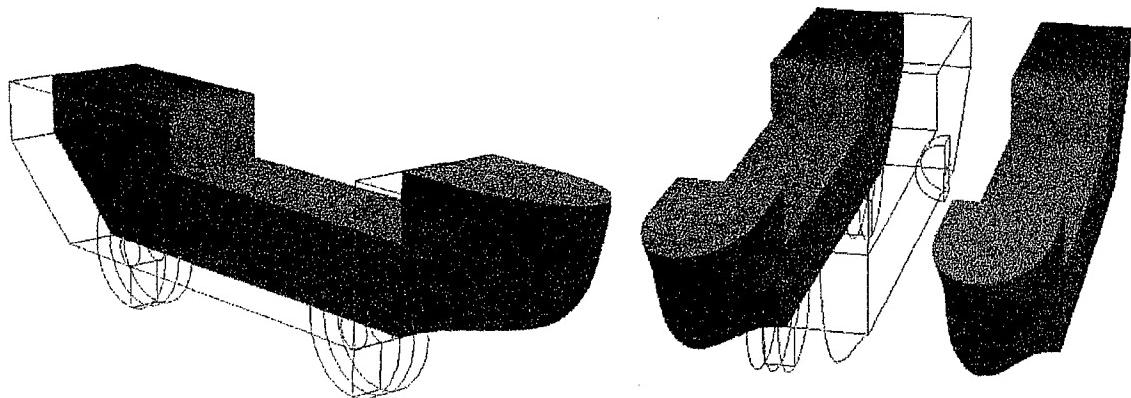


Figure A11.1 Steps in Modeling Dive Platform Catamaran (DPCAT)

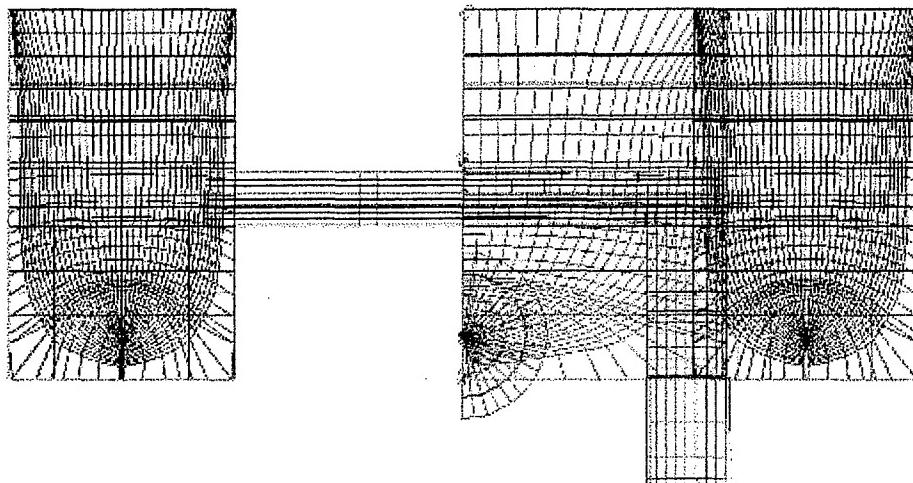


Figure A11.2 Concept of Dive Platform Catamaran (DPCAT)

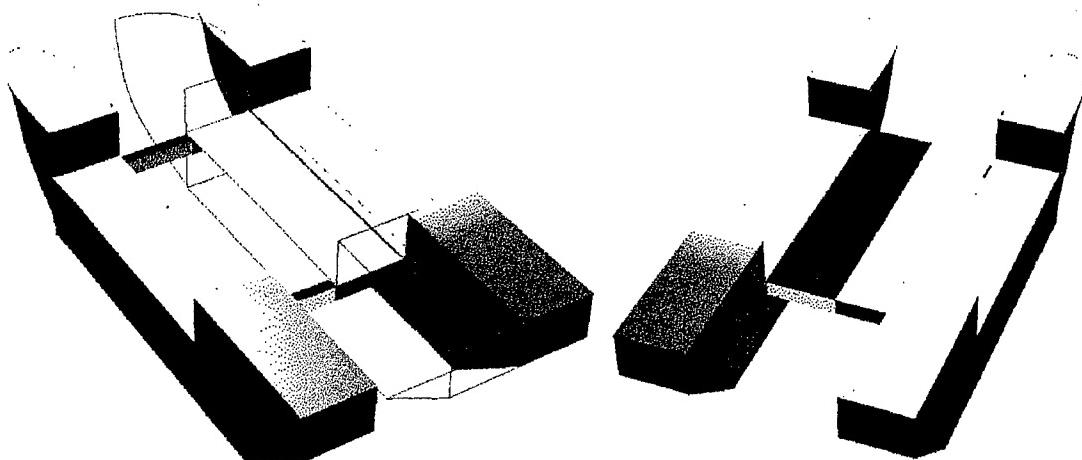


Figure A11.3 Concept of Dive Platform Catamaran (DPCAT)

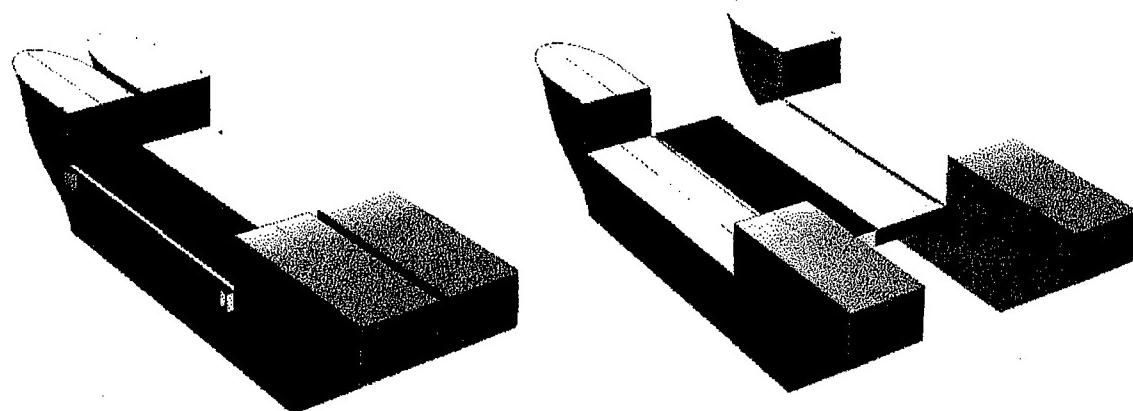


Figure A11.4 Concept of Variable Beam

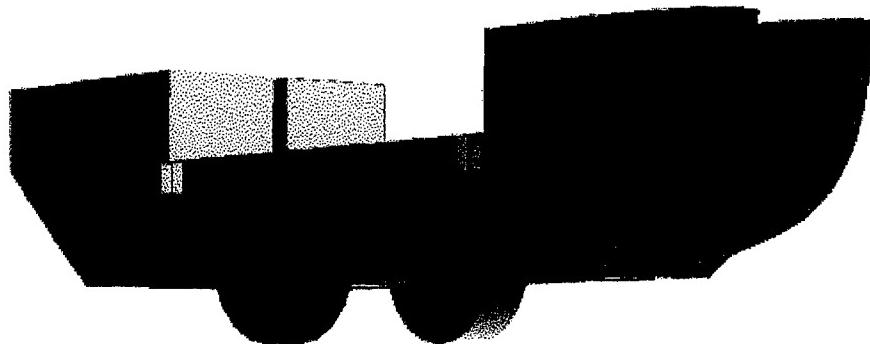


Figure A11.5 DPCAT Land Mode

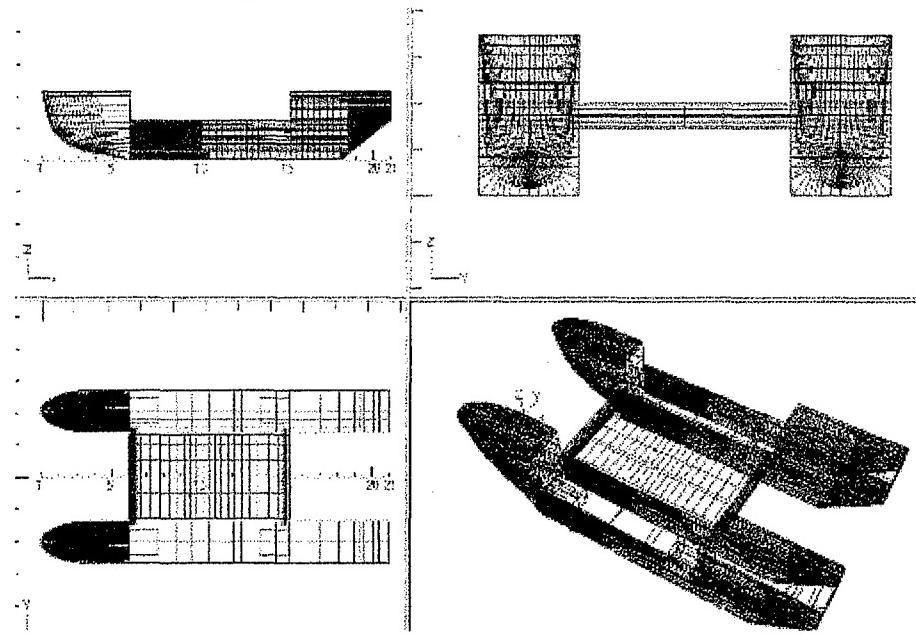
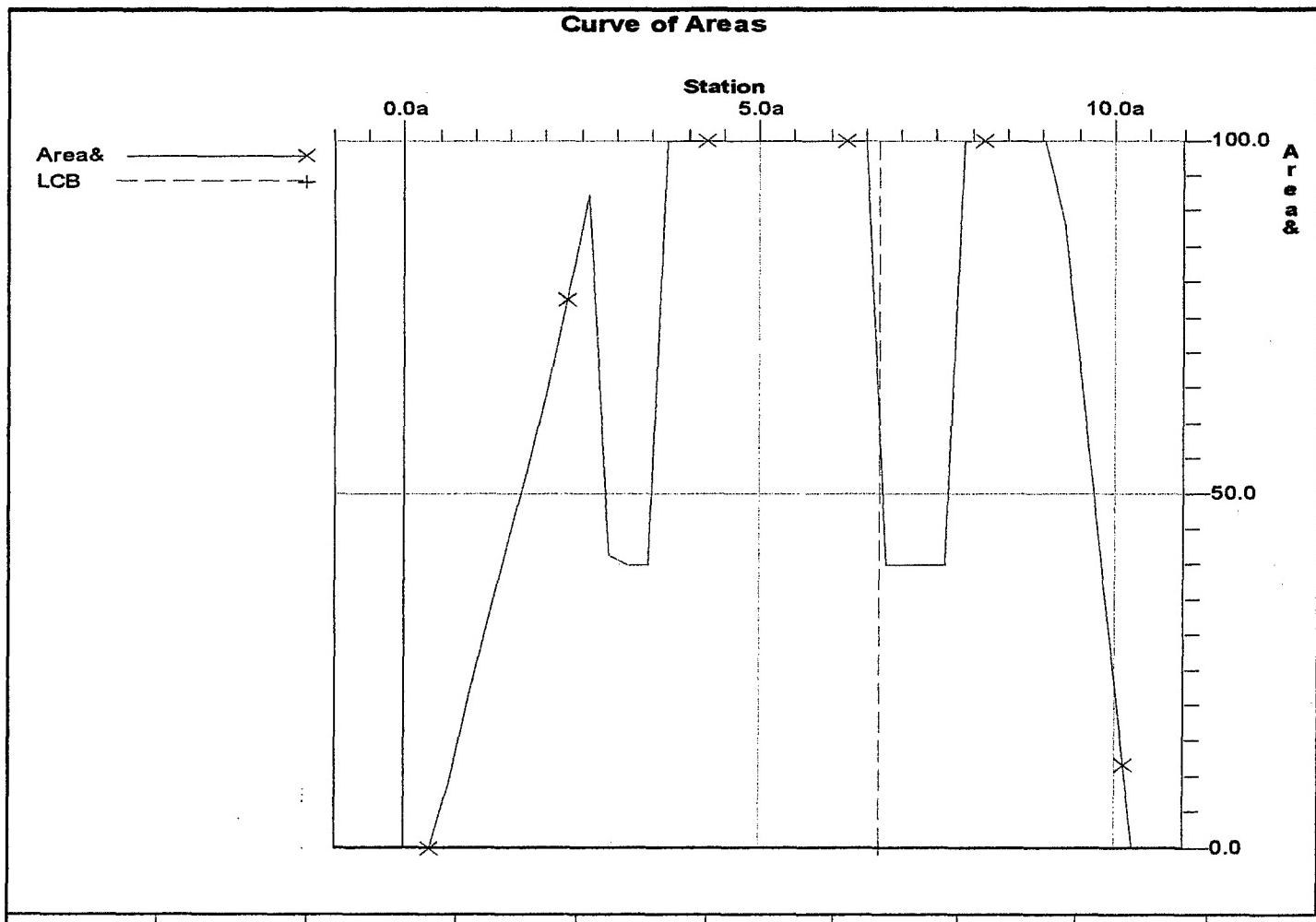


Figure A11.6 DPCAT Contour Lines

Autoship : Upright Hydrostatics Report

DPCAT Characteristics											
		DPCAT Transverse Areas									
Length Units: m		Origin Depth: 0.9000	Weight Units: mt								
Sta.	Loc	Area Sq. m			Sta	WL 1	WL 2	WL 3	WL 4	WL 5	
0.62		0.6168	0.2192		1.00		1813	1617	1568	1464	
0.9		0.8960	0.5043		1.00		2259	2455	2504	2608	
1.18		1.1752	0.7593		2.00		1494	1438	1426	1396	
1.45		1.4544	1.0145		2.00		2578	2634	2646	2676	
1.73		1.7336	1.2582		3.00	1386	1386				
2.01		2.0128	1.5205		3.00	2036	2036				
2.29		2.2920	1.8159		3.00	1646	1646				
2.57		2.5712	2.1619		3.00	2686	2686				
2.85		2.8504	0.9672		4.00	1386	1386	1386			
3.13		3.1296	0.9372		4.00	2036	2036				
3.41		3.4088	0.9372		4.00	2426	2426				
3.69		3.6880	2.3431		5.00	1386	1386	1386			
3.97		3.9672	2.3431		5.00	2686	2686	2686			
4.25		4.2464	2.3431		6.00	1386	1386	1386			
4.53		4.5256	2.3431		6.00	2686	2686	2686			
4.8		4.8048	2.3431		7.00	1386	1386	1386			
5.08		5.0840	2.3431		7.00	2686	2686	2686			
5.36		5.3632	2.3431		7.00	1386	1386				
5.64		5.6424	2.3431		7.00	2036	2036				
5.92		5.9216	2.3431		7.00	1646	1646				
6.2		6.2008	2.3431		7.00	2686	2686				
6.48		6.4800	2.3431		7.00	2036	2036				
6.76		6.7592	0.9372		7.00	2426	2426				
7.04		7.0384	0.9372		8.00	1386	1386	1386	1386	1386	
7.32		7.3176	0.9372		8.00	2686	2686	2686	2686	2686	
7.6		7.5968	0.9372		9.00	1386	1386	1386	1386	1386	
7.88		7.8760	2.3431		9.00	2686	2686	2686	2686	2686	
8.16		8.1552	2.3431		10.00				1386	1386	1386
8.43		8.4344	2.3431		10.00				2686	2686	2686
8.71		8.7136	2.3431		10.67					1386	1386
8.99		8.9928	2.3431		10.67					2686	2686
9.27		9.2720	2.0685	DPCATOUT	Group			Group			
9.55		9.5512	1.4696		Surf: Bow			Surf: BAEM AFT			
9.83		9.8304	0.8707		Surf: Hull*1			Surf: BEAM FWD			
10.11		10.1096	0.2719		Poly: Trim of Hull Side			Surf: PLATFORM			
					Poly: Trim2 of Bow Deck Plate						
					Poly: AFT Cube						
					Poly: FWD Cube						

Autoship : Upright Hydrostatics Report



Dimensions:			
L.O.A.	10.6680	L.W.L.	9.8825
Immersed Length	9.8825		
Bmax.	5.3720	B.W.L.	5.3720
Immersed Volume	16.54 cu.m.		
FW Displacement	16.537 mt	SW Displacement	16.951 mt
Centroids:			
LCB	6.6692 (36.1 % af)	LCF	7.3937 (28.8 % aft)
TCB	0.0000	VCB	0.4436
Coefficients:			
Block (Cb)	0.346	Prismatic (Cp)	0.714
Midships (Cm)	0.484	Waterplane (Cwp)	0.341
Volume (Cv)	17.134		
Areas:			
Water Plane	18.093 sq.m	Wetted Surface	79.076 sq.m
Ratios:			
L/B Ratio	1.840	D/L Ratio	476.513
Immersion:			
Load Increment / Draft Increment	18.093	mt/m	
Metacentre:			
Transverse Radius (BMT)	11.2124 m		

Autoship : Upright Hydrostatics Report

Autoship : Upright Hydrostatics Report

DPCAT Characteristics							
Buttocks							
Length Units: mm	Butt	Loc.	End1.x	End1.z	End2.x	End2.z	
Station Locations	Butt 1	-600	2667	1219	7620	1219	
Sta	Loc.	Butt 2	-500	2667	1219	7620	1219
0.00	0	Butt 3	0	2667	1219	7620	1219
1.00	1000	Butt 4	500	2667	1219	7620	1219
2.00	2000	Butt 5	1000	2667	1219	7620	1219
3.00	3000	Butt 6	1500	2667	1218	2667	1218
4.00	4000	Butt 7	1778	2667	1218	7620	913
5.00	5000	Waterlines					
6.00	6000	WL	Loc.	End1.x	End1.y	End2.x	End2.y
7.00	7000	WL 1	0	2661	-2023	9145	-1386
8.00	8000	WL 2	500	760	-2036	7620	-2036
9.00	9000	WL 3	1000	293	-2036	7590	-1500
10.00	10000	WL 4	1500	117	-2036	10668	-1386
10.67	10668	WL 5	2000	22	-2036	10668	-1386
Offset Heights							
Sta	Butt 1	Butt 2	Butt 3	Butt 4	Butt 5	Butt 6	Butt 7
1.00						1871	547
1.00						2132	2132
2.00						483	173
2.00						2132	2132
3.00	1219	1219	1219	1219	1219	1218	1218
3.00							913
4.00	1219	1219	1219	1219	1219	1218	1218
5.00	1219	1219	1219	1219	1219	1218	1218
6.00	1219	1219	1219	1219	1219	1218	1218
7.00	1219	1219	1219	1219	1219	1218	1218
7.00							913
8.00						2132	2132
9.00						2132	2132
10.00						2132	2132
10.00						705	705
							10.00

Appendix 12. DPCAT Resistance & Effective Power Calculations

File Edit Solve Settings Help		R	P	Z	Calculator
Catamaran					<input checked="" type="checkbox"/> Maintek Fast Catamaran
Project Name:			DPCAT		
LWL:	14.75				
Breadth:	5.37				
Draft (F):	0.90				
Draft (A):	0.90				
Displacement:	16.96				
L/D:	-13.90				
CWP:	0.34				
CM:	0.48				
Form Factor:	1.00				
Wetted Hull Area:	79.08				
Wetted Appendage Area:	0.00				
Wetted Transom Area:	0.00				
Transom Width:	0.00				
Hull Angle of Incidence:	31.52				
Hull Angle of Run:	0.00				
Angle at 1/4 Bulb:	0.00				
Bulbous Bow:	NO				
Transom bulb area:	0.00				
Bulb centroid location:	0.00				
Bow Type (F):	N				
Aft Type (A):	N				
Service Margin:	0.00				
Appendage Allowance:	0.00				
Appendage Form Factor:	0.00				
CF:	0.23				
CP:	0.40				

Methods - Catamarans		Calculate
<input checked="" type="checkbox"/> Maintek Fast Catamaran		<input type="button" value="Options"/>
		<input type="button" value="Speeds.."/>
		<input type="button" value="Cancel"/>

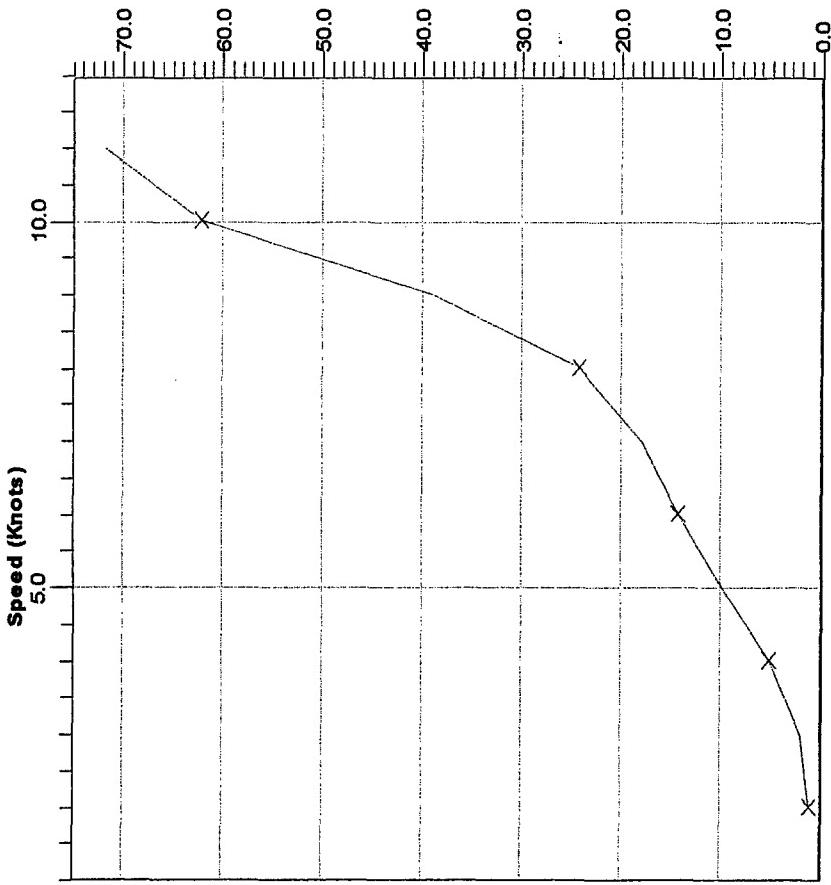
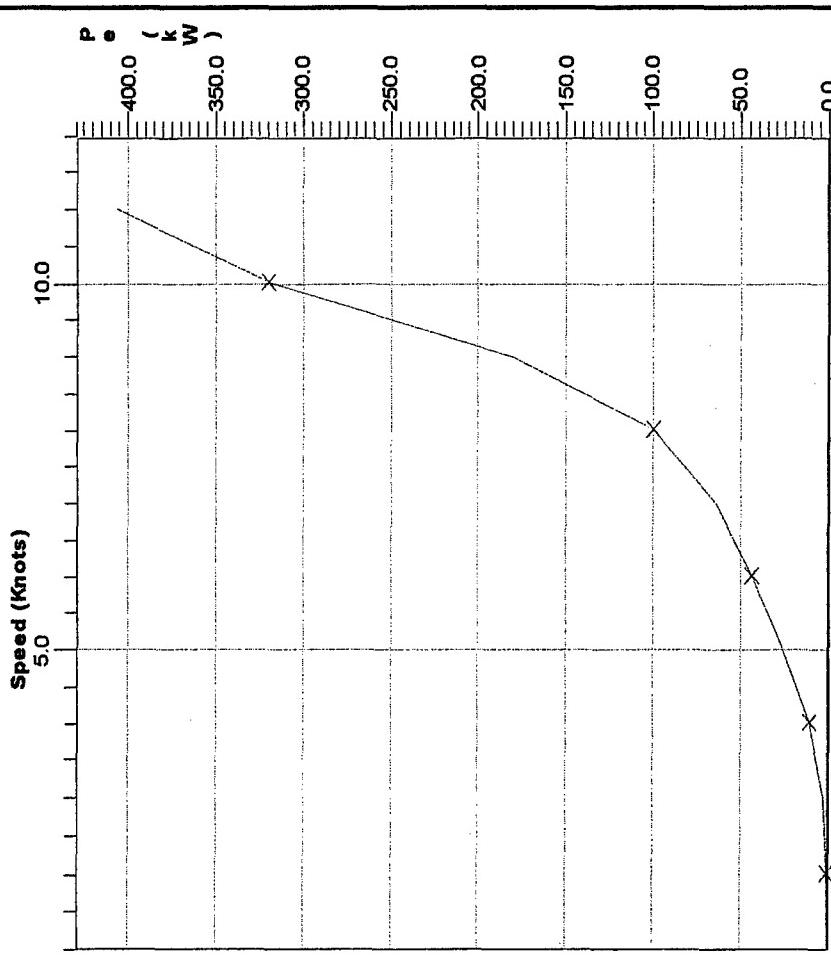
Browse Methods	
<input type="text" value="FastCat"/> <input type="button" value="..."/>	
Project : DPCAT	
FH : 0.00 - 1.71	
CB : 0.23	
CP : 0.48	
CM : 0.48	
B/T : 5.97	
L/B : 2.75	
L/D : 5.79	
LD : 5.75 - 7.00	

Resistance Options	
Hull Wetted Area:	79.08 sq m
<input type="radio"/> User Defined	<input type="radio"/> Basler
<input type="radio"/> Denny Mumford	<input type="radio"/> Averaged
Resistance Allowances	
Scale Effect:	0.00020
Air Resistance:	0.00000
Hull Roughness (m):	0.00000
Prop Diameter (m):	0.00

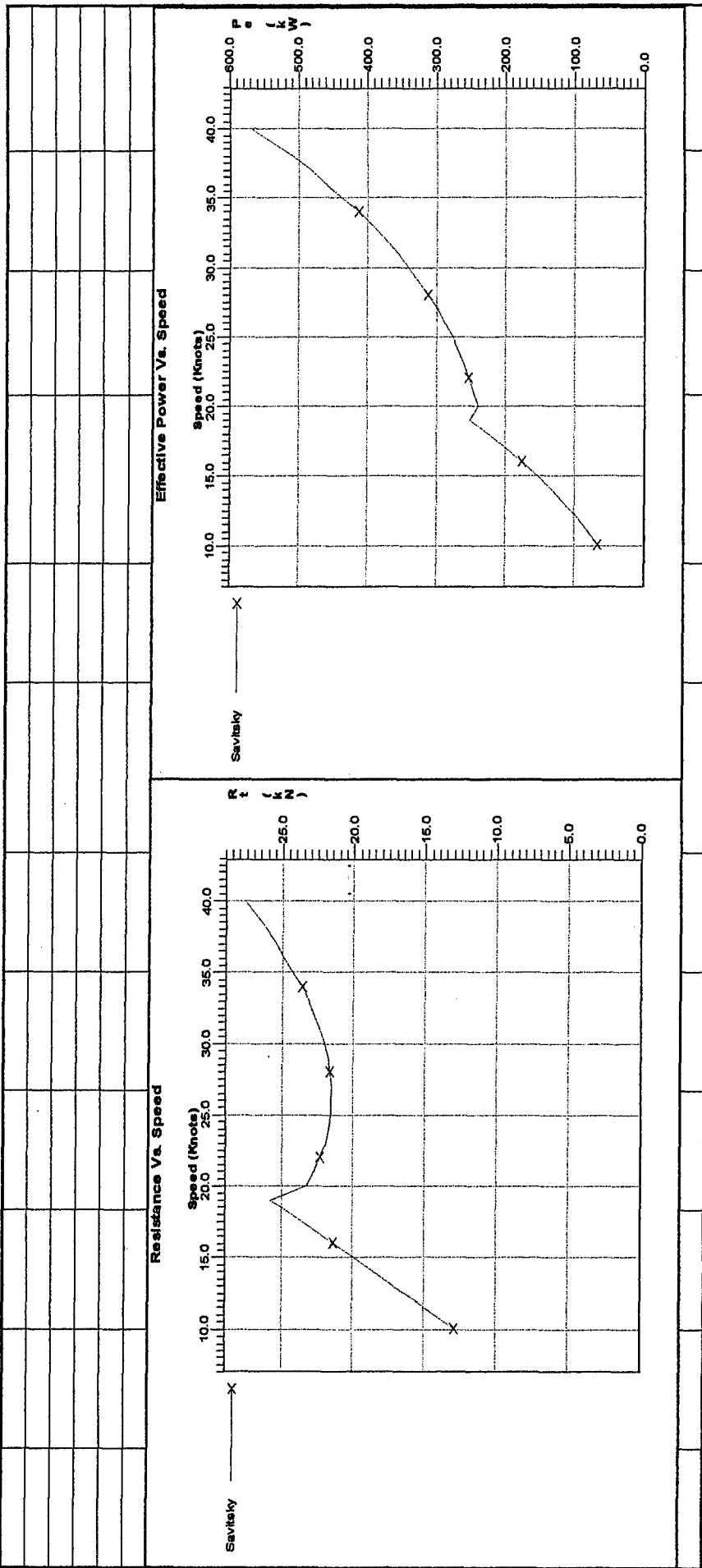
Propulsive Coefficient for Catamarans	
0.62	
<input type="radio"/> User defined	
<input checked="" type="radio"/> Waterjet Propulsion	(0.62 - 0.64)
<input type="radio"/> Propeller with inclining shaft	(0.64 - 0.65)
<input type="radio"/> Propeller with aft body tunnel	(0.70 - 0.90)
<input type="radio"/> Z-Drive	(0.68 - 0.70)

Table A12.1. Sample DPCAT AUTOPOWER Calculations Input

Prediction from AutoPower V3.0.5								Total Resistance, Effective Power, PE	
Project:	DPCAT	Date:	22 Nov 04			Speed (kt)	Fh	Rt (kN)	Compton Compton
Hull Type:	Semi-Displacement			3.00	0.16		2.07	3.20	
Hull Data				4.00	0.21		5.29	10.88	
LWL	9.88m			5.00	0.26		10.02	25.78	
Breadth	5.37m			6.00	0.31		14.32	44.20	
Draft	0.90m			7.00	0.37		17.97	64.69	
Chine Beam	5.26m			8.00	0.42		24.40	100.43	
Chine Length	7.91m			9.00	0.47		39.16	181.32	
CX	0.480			10.00	0.52		62.24	320.20	
Displacement	16.5t			11.00	0.57		71.90	406.88	
LCG	3.57m								
Half Angle of Entrance	31.52deg								
Deadrise Angle	0.0deg								
Wetted Hull Area	79.1m ²								
Wetted Transom Area	0.0m ²								
Strut Type	Single								
Shaft Angle	0.0deg								
Shaft Length	0.0m								
Shaft Diameter	0.0m								
Projected Skeg Area	0.0m ²								
Number of Sea Inlets	0								
Projected Area of Inlets	0.0m ²								
Rudder Type	0-NACA 0015								
Rudder Surface Area	0.0m ²								
Flap	NO								
Service Margin	0.00%								
Appendage Allowance	0.00%								
Service Speed	10.0knots								

Resistance Vs. Speed**Effective Power Vs. Speed**

Resistance and Power Prediction from AutoPower V3.0.5		Savitsky Method				Total Resistance, R _t (kN)	Effective Power, PE
Project	DPCAT			Speed (kt)	F _n		
Date:	22 Nov 04			10.00	0.52	12.97	66.72
Hull Type:	Planing			11.00	0.57	14.35	81.21
				12.00	0.63	15.75	97.24
				13.00	0.68	17.16	114.74
Hull Data				14.00	0.73	18.56	133.66
LWL	9.88m			15.00	0.78	19.99	154.29
Breadth	5.37m			16.00	0.84	21.42	176.33
Draft	0.90m			17.00	0.89	22.89	200.21
Chine Beam	5.26m			18.00	0.94	24.35	225.45
Chine Length	7.91m			19.00	0.99	25.81	252.32
CX	0.480			20.00	1.05	23.31	239.78
Displacement	16.5t			21.00	1.10	22.78	246.11
LCG	3.57m			22.00	1.15	22.37	253.20
Half Angle of Entrance	31.52deg			23.00	1.20	21.98	260.06
Deadrise Angle	0.0deg			24.00	1.25	21.76	268.62
Wetted Hull Area	79.1m ²			25.00	1.31	21.63	278.19
Wetted Transom Area	0.0m ²			26.00	1.36	21.60	288.89
Strut Type	Single			27.00	1.41	21.54	299.13
Shaft Angle	0.0deg			28.00	1.46	21.67	312.07
Shaft Length	0.0m			29.00	1.52	21.85	325.94
Shaft Diameter	0.0m			30.00	1.57	22.12	341.37
Projected Skeg Area	0.0m ²			31.00	1.62	22.43	357.78
Number of Sea Inlets	0			32.00	1.67	22.82	375.61
Projected Area of Inlets	0.0m ²			33.00	1.72	23.14	392.89
Rudder Type	0-NACA 0015			34.00	1.78	23.63	413.35
Rudder Surface Area	0.0m ²			35.00	1.83	24.35	438.35
Flap	NO			36.00	1.88	24.95	462.15
Service Margin	0.00%			37.00	1.93	25.44	484.32
Appendage Allowance	0.00%			38.00	1.99	26.13	510.74
Service Speed	25.0knots			39.00	2.04	26.83	538.39
				40.00	2.09	27.65	569.02

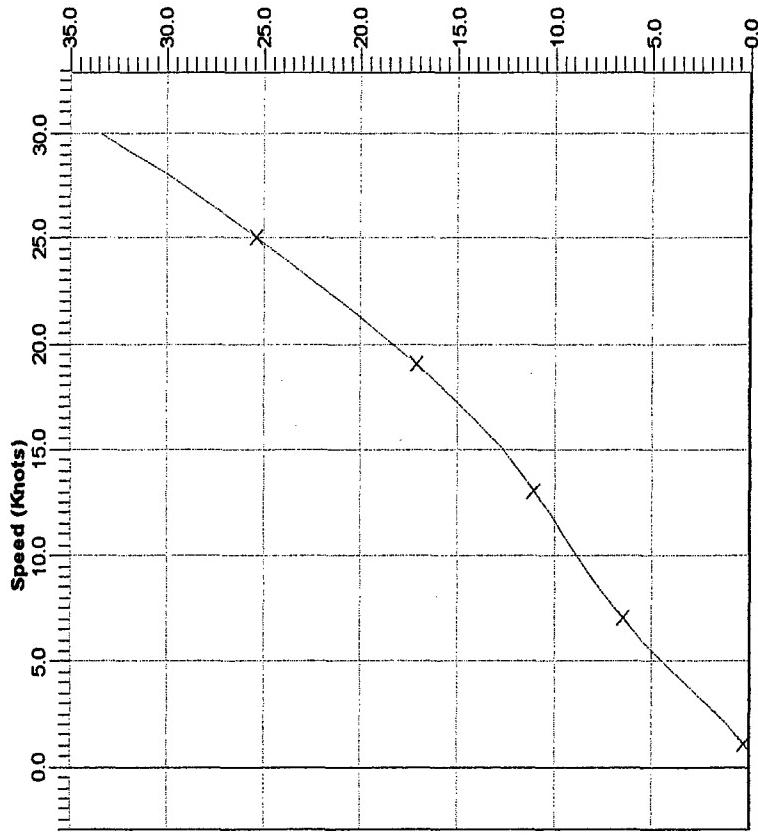
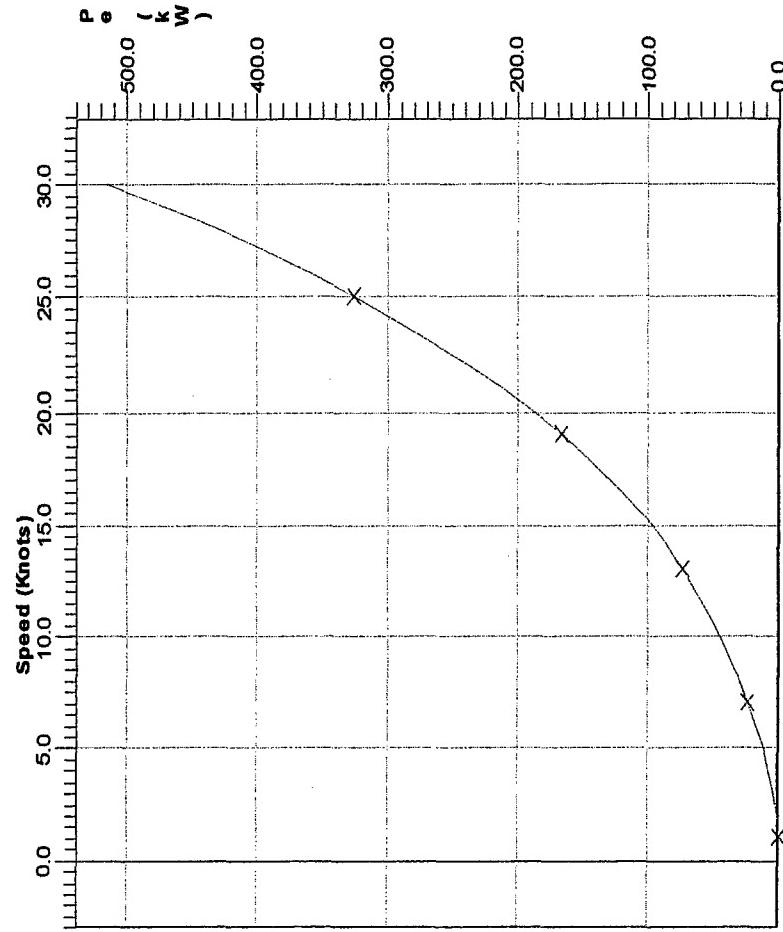


Sheet1

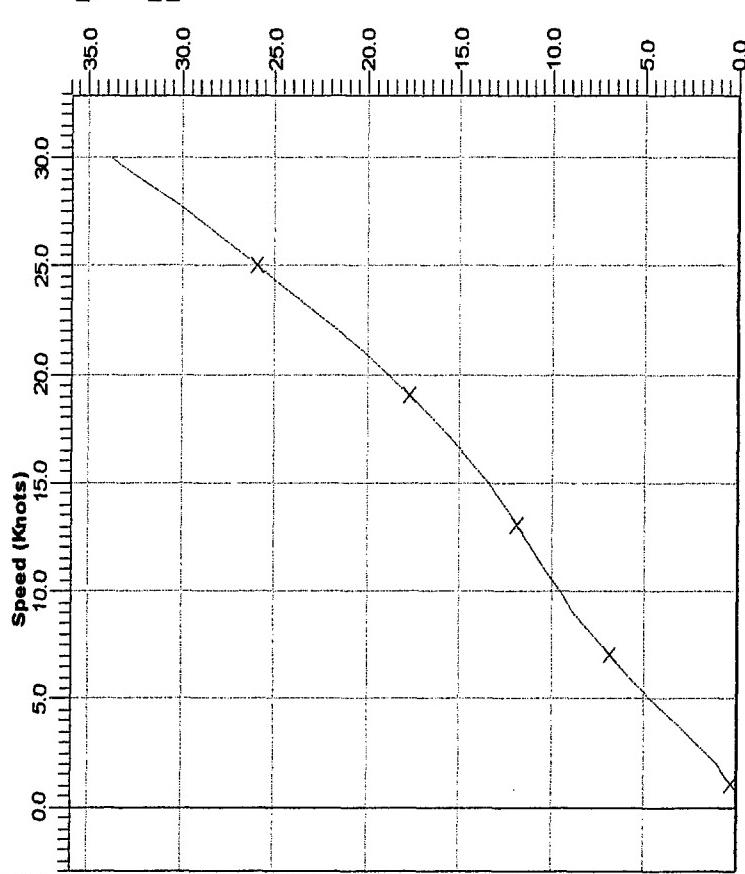
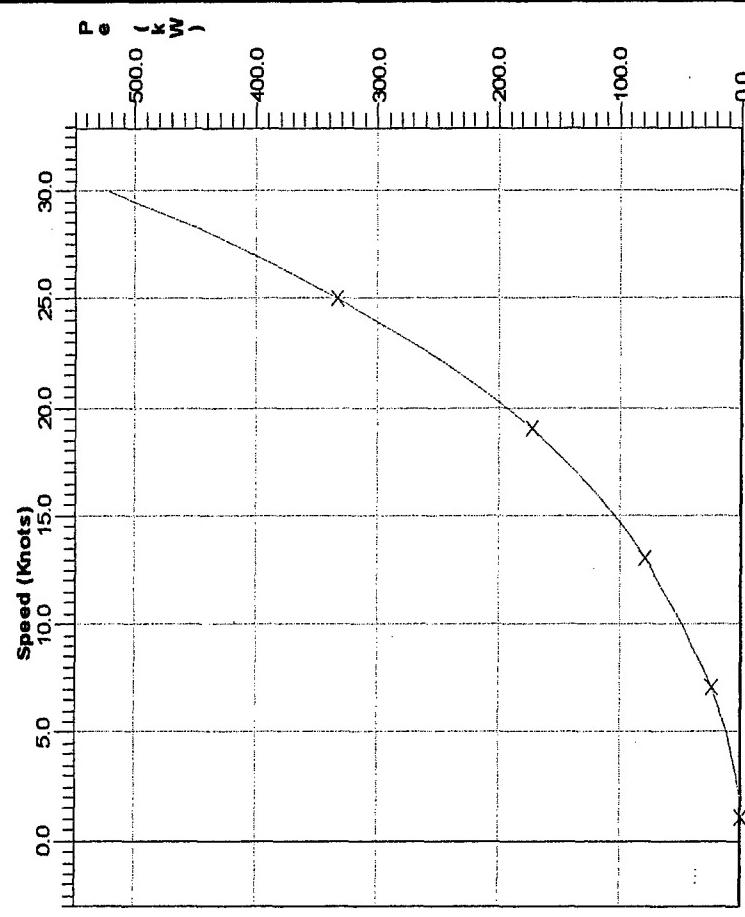
Resistance and Power Prediction from				Total Resistance, R _t (kN)		Effective Power, PE (kW)	
Project:	DPCA T	Speed (kt)	F _n	FastCat	FastCat	FastCat	FastCat
Date:	22 Nov 04	0.00	0.00	#####	#####	#####	#####
Hull Type:	Catamaran	1.00	0.05	#####	#####	#####	#####
Hull Data							
LWL	9.88m	2.00	0.10	#####	#####	#####	#####
Breadth	5.37m	3.00	0.16	#####	#####	#####	#####
Draft (F)	0.90m	4.00	0.21	#####	#####	#####	#####
Draft (A)	0.90m	5.00	0.26	#####	#####	#####	#####
Displacement	17.1t	6.00	0.31	#####	#####	#####	#####
LCB	-13.90%	7.00	0.37	#####	#####	#####	#####
Cwp	0.340	8.00	0.42	#####	#####	#####	#####
Cm	0.480	9.00	0.47	#####	#####	#####	#####
(1+K)	1.000	10.00	0.52	#####	#####	#####	#####
Wetted Hull Area	79.1m ²						
Wetted Appendages Area	0.0m ²						
Wetted Transom Area	0.0m ²						
Transom Width	0.0m						
Half Angle of Entrance	31.5deg						
Half Angle of Run	0.0deg						
Angle at 1/4 Buttock	0.0deg						
Bulbous Bow	NO						
Body Type - Fwd:	Normal						
Body Type - Aft:	Normal						
Service Margin	0.00%						
Appendage Allowance	0.00%						
Appendage Form Factor	0.0						
C _b	0.350						
C _p	0.729						
Service Speed	10.0 knots						

Sheet1

Resistance and Power Prediction from AutoPower V3.0.5				Total Resistance, R _t (kN)	Effective Power, PE (kW)
Project:	DPCAT	Date:	22 Nov 04	Speed (kt) F _n	FastCat
Hull Type:	Catamaran			0.00	0.00
LWL	12.50m		1.00	0.05	0.35
Breadth	5.37m		2.00	0.09	1.19
Draft (F)	0.90m		3.00	0.14	2.27
Draft (A)	0.90m		4.00	0.19	3.43
Displacement	10.5t		5.00	0.23	4.57
LCB	-13.90%		6.00	0.28	5.62
Cwp	0.340		7.00	0.33	6.57
Cm	0.480		8.00	0.37	7.43
(1+K)	1.000		9.00	0.42	8.20
Wetted Hull Area	79.1m ²		12.00	0.56	10.34
Wetted Appendages Area	0.0m ²		13.00	0.60	11.09
Wetted Transom Area	0.0m ²		14.00	0.65	11.90
Transom Width	0.0m		15.00	0.70	12.79
Half Angle of Entrance	31.5deg		16.00	0.74	13.76
Half Angle of Run	0.0deg		17.00	0.79	14.82
Angle at 1/4 Buttock	0.0deg		18.00	0.84	15.96
Bulbous Bow	NO		19.00	0.88	17.17
Body Type - Fwd:	Normal		20.00	0.93	18.45
Body Type - Aft:	Normal		21.00	0.98	19.78
Service Margin	0.00%		22.00	1.02	21.14
Appendage Allowance	0.00%		23.00	1.07	22.54
Appendage Form Factor	0.0		24.00	1.12	23.97
Cb	0.169		25.00	1.16	25.42
Cp	0.353		26.00	1.21	26.90
Service Speed	25.0knots		27.00	1.25	28.43
			28.00	1.30	30.01
			29.00	1.35	31.67
			30.00	1.39	33.42
					515.83

Resistance Vs. Speed**Effective Power Vs. Speed**

Prediction from AutoPower V3.0.5		DPCAT		Speed (kt) Fn		Total Resistance, Rt (kN)		Effective Power, PE (kW)	
Project:		Date:	22 Nov 04	Hull Type:	Catamaran	Speed (kt) Fn	FastCat	Speed (kt) Fn	FastCat
Hull Data						0.00	0.00	0.00	0.00
LWL	14.75m			1.00	0.04	0.34	0.18	0.18	1.21
Breadth	5.37m			2.00	0.09	1.18			
Draft (F)	0.90m			3.00	0.13	2.28			3.52
Draft (A)	0.90m			4.00	0.17	3.49			7.18
Displacement	17.0t			5.00	0.21	4.71			12.11
LCB	-13.90%			6.00	0.26	5.87			18.11
Cwp	0.340			7.00	0.30	6.94			24.98
Cm	0.480			8.00	0.34	7.91			32.56
(1+K)	1.000			9.00	0.38	8.80			40.73
Wetted Hull Area	79.1m ²			10.00	0.43	9.61			49.46
Wetted Appendages Area	0.0m ²			11.00	0.47	10.39			58.79
Wetted Transom Area	0.0m ²			12.00	0.51	11.15			68.80
Transom Width	0.0m			13.00	0.56	11.91			79.67
Half Angle of Entrance	31.5deg			14.00	0.60	12.72			91.58
Half Angle of Run	0.0deg			15.00	0.64	13.57			104.74
Angle at 1/4 Buttock	0.0deg			16.00	0.68	14.50			119.35
Bulbous Bow	NO			17.00	0.73	15.50			135.58
Body Type - Fwd:	Normal			18.00	0.77	16.59			153.61
Body Type - Aft:	Normal			19.00	0.81	17.75			173.53
Service Margin	0.00%			20.00	0.86	18.99			195.42
Appendage Allowance	0.00%			21.00	0.90	20.30			219.30
Appendage Form Factor	0.0			22.00	0.94	21.66			245.19
Cb	0.232			23.00	0.98	23.08			273.03
Cp	0.484			24.00	1.03	24.53			302.80
Service Speed	25.0knots			25.00	1.07	26.01			334.47
				26.00	1.11	27.51			368.03
				27.00	1.15	29.05			403.52
				28.00	1.20	30.62			441.04
				29.00	1.24	32.23			480.77
				30.00	1.28	33.88			522.95

Resistance Vs. Speed**Effective Power Vs. Speed**

Sheet1

Prediction from AutoPower V3.0.5		DPCAT				Total Resistance, R _t (kN)	Effective Power, PE (kW)
Project:		Date:	22 Nov 04	Speed (kt) F _n	FastCat	FastCat	FastCat
Hull Type:	Catamaran			0.00	0.00	0.00	0.00
Hull Data				1.00	0.05	0.35	0.18
LWL	9.88m			2.00	0.10	1.16	1.19
Breadth	5.37m			3.00	0.16	2.17	3.34
Draft (F)	0.90m			4.00	0.21	3.21	6.60
Draft (A)	0.90m			5.00	0.26	4.20	10.80
Displacement	5.2t			6.00	0.31	5.09	15.71
LCB	-13.90%			7.00	0.37	5.88	21.17
Cwp	0.340			8.00	0.42	6.59	27.12
Cm	0.480			9.00	0.47	7.25	33.56
(1+K)	1.000			10.00	0.52	7.89	40.61
Wetted Hull Area	79.1m ²			11.00	0.57	8.56	48.44
Wetted Appendages Area	0.0m ²			12.00	0.63	9.28	57.26
Wetted Transom Area	0.0m ²			13.00	0.68	10.06	67.29
Transom Width	0.0m			14.00	0.73	10.93	78.74
Half Angle of Entrance	31.5deg			15.00	0.78	11.89	91.76
Half Angle of Run	0.0deg			16.00	0.84	12.93	106.45
Bulbous Bow	NO			17.00	0.89	14.05	122.89
Angle at 1/4 Buttock	0.0deg			18.00	0.94	15.23	141.05
Body Type - Fwd:	Normal			19.00	0.99	16.46	160.92
Body Type - Aft:	Normal			20.00	1.05	17.73	182.44
Service Margin	0.00%			21.00	1.10	19.03	205.59
Appendage Allowance	0.00%			22.00	1.15	20.36	230.38
Appendage Form Factor	0.0			23.00	1.20	21.71	256.92
C _b	0.106			24.00	1.25	23.11	285.38
C _p	0.221			25.00	1.31	24.57	316.05
Service Speed	25.0knots			26.00	1.36	26.11	349.28
				27.00	1.41	27.75	385.45
				28.00	1.46	29.50	424.88
				29.00	1.52	31.35	467.70
				30.00	1.57	33.28	513.61

